Fishery Data Series No. 00-32

Inriver Abundance, Spawning Distribution, and Migratory Timing of Copper River Chinook Salmon in 1999

Matthew J. Evenson

and

Klaus G. Wuttig

November 2000

Alaska Department of Fish and Game

Division of Sport Fish

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used in Division of Sport Fish Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications without definition. All others must be defined in the text at first mention, as well as in the titles or footnotes of tables and in figures or figure captions.

Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
metric ton	mt
milliliter	ml
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
ounce	oz
pound	lb
quart	qt
yard	yd
Spell out acre and ton.	

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
hour (spell out for 24-hour clock)	h
minute	min
second	s
Spell out year, month, and week.	

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	Hp
hydrogen ion activity	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

All commonly accepted abbreviations.	e.g., Mr., Mrs., a.m., p.m., etc.
All commonly accepted professional titles.	e.g., Dr., Ph.D., R.N., etc.
and	&
at	@
Compass directions:	
east	E
north	N
south	S
west	W
Copyright	©
Corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
et alii (and other people)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.,
id est (that is)	i.e.,
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
number (before a number)	# (e.g., #10)
pounds (after a number)	# (e.g., 10#)
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S. state and District of Columbia abbreviations	use two-letter abbreviations (e.g., AK, DC)

Mathematics, statistics, fisheries

alternate hypothesis	H_A
base of natural logarithm	e
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	F, t, χ^2, etc.
confidence interval	C.I.
correlation coefficient	R (multiple)
correlation coefficient	r (simple)
covariance	cov
degree (angular or temperature)	°
degrees of freedom	df
divided by	÷ or / (in equations)
equals	=
expected value	E
fork length	FL
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_2, etc.
mideye-to-fork	MEF
minute (angular)	'
multiplied by	x
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
standard length	SL
total length	TL
variance	Var

FISHERY DATA SERIES NO. 00-32

INRIVER ABUNDANCE, SPAWNING DISTRIBUTION, AND MIGRATORY TIMING OF COPPER RIVER CHINOOK SALMON IN 1999

by

Matthew J. Evenson,
and
Klaus G. Wuttig
Division of Sport Fish, Fairbanks

Alaska Department of Fish and Game
Division of Sport Fish, Research and Technical Services
333 Raspberry Road, Anchorage, Alaska, 99518-1599

November 2000

Development and publication of this manuscript were partially financed by the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under Projects F-10-15, Job No. S-3-1(b).

The Fishery Data Series was established in 1987 for the publication of technically-oriented results for a single project or group of closely related projects. Fishery Data Series reports are intended for fishery and other technical professionals. Fishery Data Series reports are available through the Alaska State Library and on the Internet: http://www.sf.adfg.state.ak.us/statewide/divreports/html/intersearch.cfm This publication has undergone editorial and peer review.

Matthew J. Evenson and Klaus G. Wuttig
Alaska Department of Fish and Game, Division of Sport Fish, Region III,
1300 College Road, Fairbanks, AK 99701-1599, USA

This document should be cited as:
Evenson, M. J. and Wuttig, K. G. 2000. Inriver abundance, spawning distribution, and migratory timing of Copper River chinook salmon in 1999. Alaska Department of Fish and Game, Fishery Data Series No. 00-32, Anchorage.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

Radiotelemetry and mark-recapture techniques were used to estimate inriver abundance, spawning distribution, and migratory time-density functions of chinook salmon *Onchorhynchus tshawytscha* in the Copper River during 1999. Inriver abundance was estimated using two-sample mark-recapture techniques where radio tags were applied as the primary mark. A total of 522 chinook salmon were captured, tagged, and released during the first sample along both shores of the Copper River downstream from the lower boundary of the Chitina Subdistrict personal use (PU) salmon fishery from May 20- August 2, 1999. The harvest of 5,728 chinook salmon in the PU fishery, determined from returns of fishing permits, was used as the second sample. Ninety-two fish with tags were recovered in the PU fishery. Four of these were not reported by fishers but were inferred harvested from data recorded by stationary radio tracking stations positioned at the upper and lower boundaries of the fishery. A temporally-stratified estimator was used to estimate abundance for the period June 8-July 26 when the fishery was prosecuted. Estimated abundance during this period was 28,810 (SE=3,311) chinook salmon >570 mm MEF. This estimate was expanded, based on CPUE information from the first sample, to account for the portion of the run that passed prior to the opening of the fishery. Total abundance was estimated to be 32,090 (SE=3,814) chinook salmon >570 mm MEF.

Estimated distribution of spawning chinook salmon was proportioned from 356 radio tags located in spawning areas. The smallest proportion returned to the Tazlina River drainage (0.030; SE=0.021), and the largest proportion returned to the Klutina River drainage (0.237; SE=0.021). The lower portion of the Copper River drainage, which includes the Chitina, Tonsina, Klutina, and mainstem Copper rivers, accounted for a large proportion (0.761) of the returning fish. The nine streams normally used for the aerial survey indices accounted for 0.241 (SE=0.019) of chinook salmon migrating into all spawning streams. The Gulkana River accounted for 0.474 of fish located in the nine streams. Mainstem spawners accounted for 0.788 (SE=0.032) and 0.761 (SE=0.037) of all spawning chinook salmon in the Tonsina and Klutina rivers, respectively.

Migratory time-density functions at the capture site varied among the major spawning stocks. Mean date of passage ranged from June 10 for chinook salmon bound for the upper Copper River drainage to July 4 for mainstem spawners in the Klutina drainage. Migratory timing of chinook salmon bound for tributaries in the Tonsina and Klutina rivers was generally earlier than their mainstem spawning counterparts. Comparison of migratory timing for nine spawning stocks indicated three distinct groups with similar mean dates of passage.

Key words: chinook salmon, *Onchorhynchus tshawytscha*, Copper River, abundance, mark-recapture, radiotelemetry, spawning distribution, time-density functions.

INTRODUCTION

The Copper River supports a large and commercially important run of chinook salmon *Oncorhynchus tshawytscha*. These fish are harvested by a commercial fishery operating in and near the mouth of the river and also by in-river subsistence, personal use, and sport fisheries. Recent 5-year annual harvest (1994-1998) has averaged 72,094 chinook salmon (Taube *In prep*). Harvests by sport anglers have increased substantially in recent years with the Gulkana and Klutina rivers accounting for the majority of the harvest.

The return of salmon in the Copper River is managed under guidelines established in: 1) the *Copper River District Salmon Management Plan* (AAC 2000a); 2) the *Copper River Chinook Salmon Fishery Management Plan* (AAC 2000b); and, 3) the *Copper River Subsistence Salmon Fisheries Management Plan* (AAC 2000c). Together, these management plans mandate the Alaska Department of Fish and Game (ADF&G) to manage Copper River salmon to ensure subsistence needs and biological escapement goals are met. During a 1999 meeting (after this study was conducted), the Alaska Board of Fisheries (BOF) declared that the PU salmon dip net fishery in the Chitina Subdistrict met criteria for customary and traditional subsistence use and mandated the fishery be managed as a subsistence fishery. The Board determined that 130,000 – 150,000 salmon were necessary for meeting the Chitina Subdistrict subsistence needs, and a biological escapement goal of 28,000–55,000 chinook salmon was necessary to ensure high sustained yields. Prior to these rulings, the commercial fishery was managed to ensure a spawning escapement of 17,500 salmon other than sockeye salmon *Oncorhynchus nerka.* No species-specific escapement goals or harvest guidelines had been established for chinook salmon.

This project was initiated in response to a 1996 BOF meeting that imposed a sunset clause for existing management plans effective in 2002, at which time new plans were to be written based on new data collected by ADF&G. This project, along with a coded wire tagging project designed to estimate relative exploitation rates in the commercial fishery and a study to estimate historic returns of chinook salmon using catch-age analysis are ADF&G-Sport Fish Division's response to the Board's directive.

With the exception of a weir count in the Gulkana River in 1996 (LaFlamme 1997), aerial counts in select spawning tributaries have been the sole measure of chinook salmon spawning escapement. A total of 40 spawning streams have been identified throughout the drainage, but only nine are surveyed on a regular basis. The sonar at Miles Lake provides a total count of all salmon, but does not apportion the count for the various species. This project was the second year of a four-year study, and should ultimately lead to a reliable, cost-effective method to assess chinook salmon escapement in the Copper River.

OBJECTIVES

The objectives of this study were to:

1. estimate the inriver abundance of chinook salmon in the Copper River at the point of entry into the Chitina Subdistrict personal use (PU) fishery;
2. estimate the proportions of spawning chinook salmon in the Copper River in each major spawning tributary (Chitina, Tonsina, Klutina, Tazlina, Gulkana, and Chistochina rivers); and,
3. estimate the proportion of chinook salmon spawning in the nine tributaries assessed during aerial surveys in 1999 (Little Tonsina River, Grayling Creek, St. Anne Creek, Manker Creek, Mendeltna Creek, Kiana Creek, Gulkana River, East Fork Chistochina River, and Indian Creek).

A project task was to:

1. describe the stock-specific migratory time-density functions (timing profiles) at the entry point to the PU fishery, where stocks are defined as those chinook salmon spawning in the Chitina, Tonsina, Klutina, Tazlina, Gulkana, and Chistochina rivers.

METHODS

Study Design (Overview)

Chinook salmon were captured and implanted with radio tags in the mainstem Copper River immediately downstream from the PU dip net fishery near Chitina, Alaska (Figure 1). Five hundred twenty-two radio tags were deployed over the span of the run. Subsequent migrations of these fish were monitored with a combination of automated tracking stations positioned at various points throughout the drainage and aerial tracking surveys using fixed wing aircraft. Proportions of fish spawning in various tributaries were estimated as the ratio of numbers of radio-tagged fish migrating into a specific tributary to the total number of radio tags surviving and migrating into all spawning streams. The farthest upstream location for each fish in a tributary stream was used to identify probable spawning areas. Migratory timing profiles of the major spawning stocks at the entry point of the PU fishery were identified using the date and time of initial capture. Harvest information and tag recoveries from the PU fishery was used to estimate the marked fraction of the population in the fishery and inriver abundance of chinook salmon at the point of entry into the fishery.

Capture and Tagging Methods

Chinook salmon were captured from two locations in the Copper River approximately 1-3 km below the lower boundary of the PU fishery from May 20-August 2, 1999 (Figure 2). Chinook salmon were captured by drifting dip nets from a river boat along the nearshore areas on both the east and west banks. Both drift areas were near long gravel bars with water levels dropping off gradually moving away from shore.

A three person crew was used to capture chinook salmon. One person piloted the boat and two crew members positioned in the bow of the boat manned the dip nets. Dip nets were commercially manufactured and constructed from solid-core aluminum tubing. Net heads were rectangular-shaped (122 cm wide x 88 cm high) and were attached to tubular fiberglass handles (3-4 m long x 1.3 cm diameter). The attached net bags were constructed with knotted nylon (8.9-10.2 cm stretch measure) and were 1.3 m deep. Plastic shovel handles capped the fiberglass handles to facilitate handling and to maintain orientation of the net head perpendicular to the direction of the drifting riverboat. At the start of each drift, the boat was positioned nearshore with the bow facing upstream.

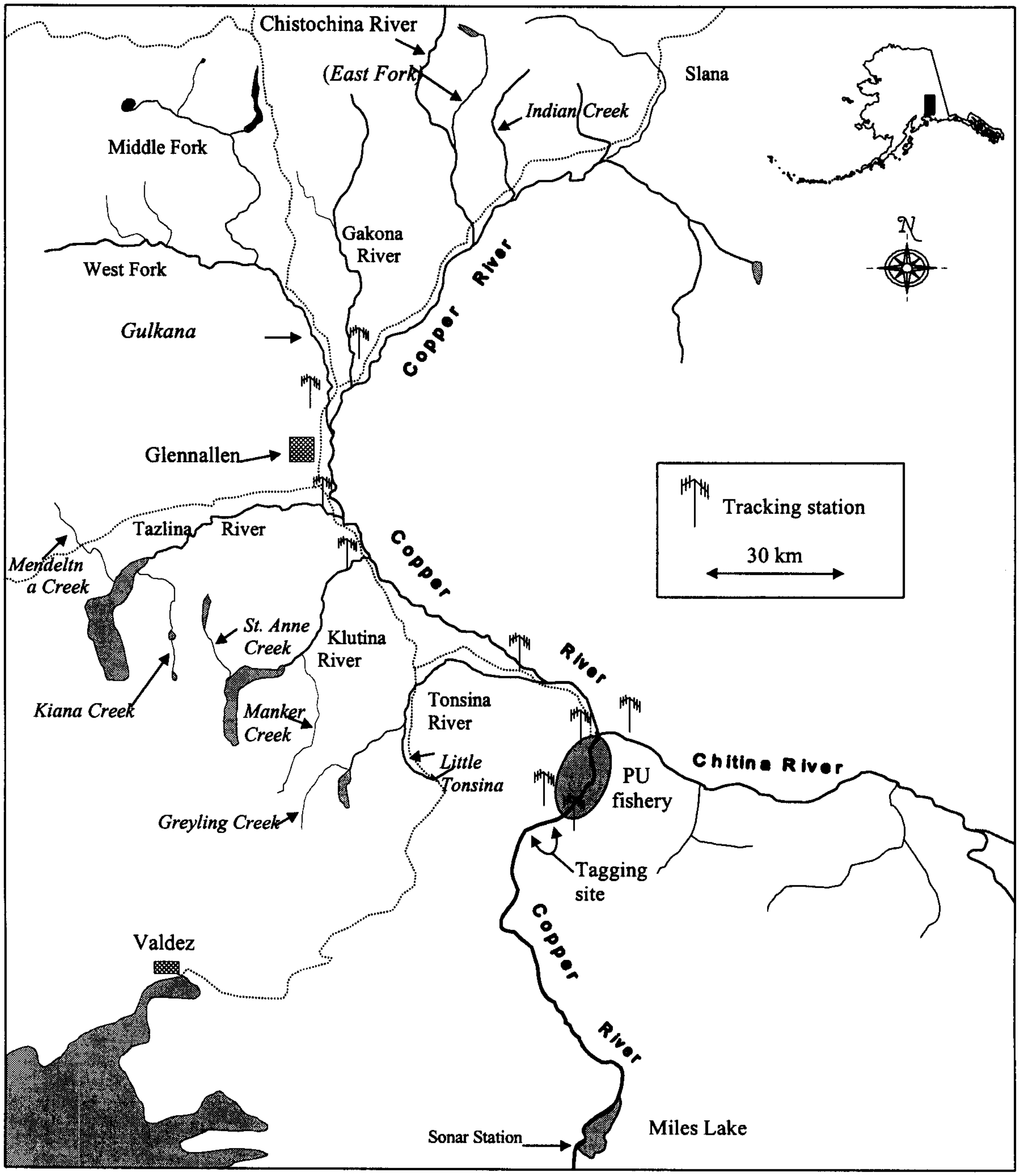

Figure 1.-Map of the Copper River drainage demarcating the tagging site, boundaries of the personal use (PU) fishery, and location of nine radio tracking stations, 1999.

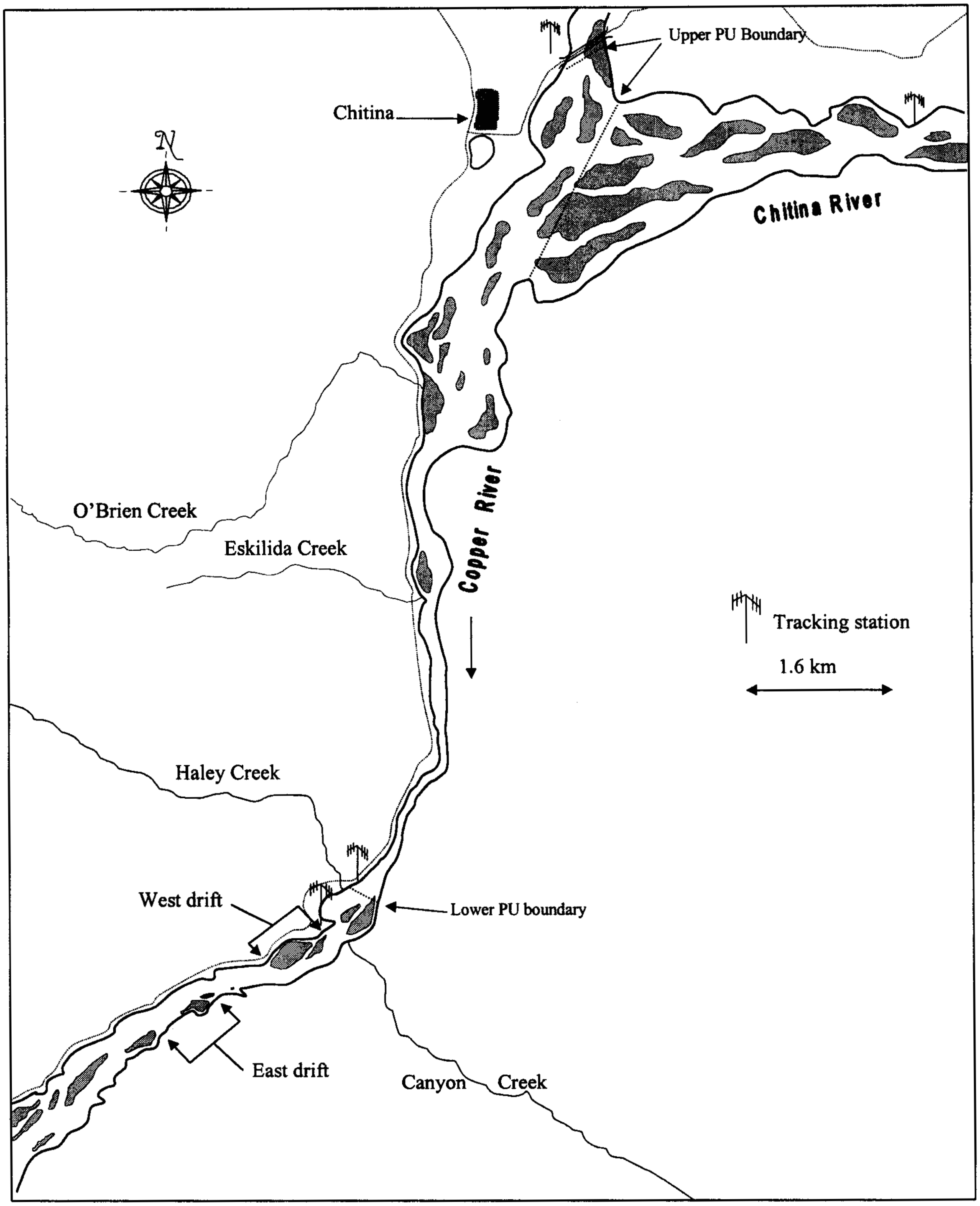

Figure 2.-Detailed map demarcating the capture and tagging location (east and west drifts), boundaries of the personal use (PU) fishery, and locations of four tracking stations positioned at the lower and upper boundaries of the PU fishery.

Distances from shore varied depending on water levels. Typically drifts were conducted 3-10 m from shore, but were occasionally conducted as far as 50 m offshore. The boat was then idled downstream, stern first, such that the velocity of the boat was slightly faster than the current at the bottom of the water column, which ensured that the dip nets remained open or "bagged" when facing downstream. The dip nets were positioned vertically in the water column from the side of the boat so that the flat edge of the dip net lightly bounced off the bottom.

Attempts were made to standardize fishing effort to help ensure that all chinook salmon migrating upstream had equal probabilities of capture. From May 26 to June 30, six hours of fishing was conducted each day with three hours of effort expended between 0800 and 1300 hours and three hours between 1800 and 2300 hours. During each three-hour session, fishing was alternated between the east and west banks every 45 min. Measurements of fishing effort included the time required to motor upstream to the start of a drift and the time required to drift back downstream to the bottom of the drift, but did not include time required to sample fish or time spent travelling to the opposite bank. After June 30 the total amount of fishing effort was reduced to five hours each day. However, equal fishing effort between the east and west banks was maintained each day. Mechanical difficulties resulted in no fishing occurring on July 3 and July 4.

Once a chinook salmon was captured, it was placed into a holding tub until the drift was completed. Duration of the drifts varied from 5 to 20 min depending on water levels and catch rates with most drifts lasting 15 min. Drifts were terminated once three fish were captured to minimize crowding stress and holding time. Upon completion of a drift, the boat was anchored in calm, backwater areas where the fish were processed and released. All fish were measured to the nearest 5-mm MEF and sex was determined from external characteristics. All fish received a uniquely numbered, yellow spaghetti tag constructed of a 5-cm section of Floy tubing shrunk onto a 38-cm piece of 80-lb monofilament fishing line (Pahlke and Etherton 1999). The monofilament was sewn through the musculature of the fish 1-2 cm ventral to the insertion of the dorsal fin between the third and fourth fin rays from the posterior of the dorsal fin. Three scales were removed from the left side of the fish approximately two rows above the lateral line along a diagonal line downward from the posterior insertion of the dorsal fin to the anterior insertion of the anal fin (Welander 1940). Scale impressions were later made on acetate cards and viewed at 100X magnification using equipment similar to that described by Ryan and Christie (1976). Ages were determined from scale patterns as described by Mosher (1969).

Because it was anticipated that a greater number of fish would be captured than the number of radio tags available, not every captured fish was implanted with a radio tag. Daily tagging rates were varied based on historic run timing through the PU fishery and the daily catch rates to ensure that enough radio tags were available for deployment over the duration of the run.

Chinook salmon that received radio tags were placed in a tagging cradle submerged in a tub of water. Radio tags were inserted through the esophagus and into the upper stomach using a 45-cm polyvinyl chloride (PVC) tube with a diameter equal to that of the radio tags. The end of the PVC tube was slit lengthwise allowing for the antenna end of the radio transmitter to be seated into the tube and held in place by friction. The radio transmitter was pushed through the esophagus and was seated using a PVC plunger, slightly smaller than the inside diameter of the first tube, such that the antenna end of the radio tag was 1 cm beyond the base of the pectoral fin. The entire handling process required approximately three minutes per fish.

RADIO-TRACKING EQUIPMENT AND TRACKING PROCEDURES

Radio tags were Model Five pulse encoded transmitters made by ATS[1]. Each radio tag was distinguishable by its frequency and encoded pulse pattern. Forty-eight frequencies spaced approximately 20 kHz apart in the 149-150 MHz range with up to 10 encoded pulse patterns per frequency were used for a total of 470 uniquely identifiable tags. Radio tags returned from the PU fishery were later reimplanted into new fish thereby increasing the number of radio tags available for deployment.

Migrating radio-tagged chinook salmon were tracked along the course of the Copper River using nine stationary tracking stations (Figure 1) similar to that described by Eiler (1995). Each station was composed of a marine deep cycle battery, a solar array, an ATS model 5041 Data Collection Computer (DCC II), an ATS model 4000 receiver, an antenna switching box, a water-proof metal housing box, and two four-element yagi antennas. The receiver and DCC II were programmed to scan through the frequencies at three-second intervals receiving with both antennas simultaneously. When a radio signal of sufficient strength was encountered the receiver paused for five seconds, at which time the tag frequency, code, signal strength, date, time, and antenna number were recorded by the data logger. Cycling through all frequencies required 5-15 minutes depending on the number of active tags in reception range. Data were downloaded onto a portable computer every 7-10 days.

Two stations were placed on the west bank of the Copper River downstream from the PU fishery: one directly below the lower boundary marker and one approximately 500 m downstream. A third station was placed on the north bank of the Chitina River approximately 6 km upstream from its confluence with the Copper River. The fourth station was placed on a west-side bluff of the Copper River immediately upstream from the upper boundary of the PU Fishery (Figure 2). These four stations, in combination, were used to identify all chinook salmon entering and exiting the PU fishery. Fish entering the Tonsina, Klutina, Tazlina, and Gulkana rivers were recorded by stations placed near the mouths of these rivers. These latter stations experienced negligible reception of transmitter signals in waters of the mainstem Copper River. The ninth station was placed on the mainstem Copper River approximately 2 km downstream from the mouth of the Gakona River (Figure 1). This station enumerated all fish spawning upstream of the Gulkana River.

The distribution of radio-tagged chinook salmon throughout the Copper River drainage was further determined by aerial tracking from small aircraft to locate tags in spawning tributaries other than those monitored with tracking stations, to locate fish that the tracking stations failed to record, and to further validate that a fish recorded on one of the data loggers did migrate into a particular stream. Three aerial tracking excursions of the

---

[1] Advanced Telemetry Systems, Isanti, Minnesota. Use of this company name does not constitute endorsement, but is included for scientific completeness.

Copper River and Chitina River drainages upstream of the PU fishery were conducted on June 24–27, July 22–24, and August 25–28. During the August 25–28 excursion, the Copper River from the Chitina River downstream to the Bremner River (downstream of the PU fishery) was also surveyed. In addition, surveys of the Klutina and Tonsina rivers were flown on August 1, 12, and 19 to determine the proportion of mainstem spawning in each river. Generally, locations of radio-tagged fish were determined with an accuracy of ±2 km, except that locations of radio-tagged fish near a tributary confluence were determined within approximately 200 m.

Tag returns from PU, subsistence, and sport fishers were encouraged by offering a $200 lottery reward. Both radio and Floy tags were printed with return and lottery information, and informational flyers were posted at the Chitina permit station and at various ADF&G offices.

Based on location data from the tracking stations, aerial surveys, or from tag return information, each radio tag was assigned a final fate (Table 1).

ESTIMATION OF INRIVER ABUNDANCE

Inriver abundance of chinook salmon was estimated using two-sample mark-recapture techniques. Fish were captured and marked with radio tags and individually numbered spaghetti tags during the first sample downstream from the lower boundary of the PU fishery as described above. Only chinook salmon that were given a radio-tag and a spaghetti tag were considered in the experiment. The harvest reported in the PU fishery through a permit system was used as the second sample in the experiment. The permits required fishers to record the total number of chinook salmon harvested (maximum of four per permit) and the date these fish were harvested. Radio tags from harvested fish were returned by PU fishers. Fishers returning tags were queried for information regarding date and location of capture. The number of radio tags that entered the PU fishery was determined from information recorded on the data loggers located at the lower end of the PU fishery. Those radio-tagged fish that did not migrate into the PU fishery were not considered in the experiment. Length and sex data were collected from a sample of the harvest.

Conditions for a Consistent Estimator

For the estimate of abundance from this mark-recapture experiment to be unbiased, certain conditions must have been met (Seber 1982). These conditions expressed in the circumstances of this study along with their respective design considerations, test procedures, and necessary adjustments for significant test results are described below:

Handling and tagging does not make a fish more or less vulnerable to capture in the PU fishery than untagged fish.

Design Considerations: Holding time of all captured fish was kept to a minimum. Obviously stressed fish (fish that were slow to recover from tagging) or injured fish were not tagged. Transit times from capture site to lower boundary of fishery and transit times through the PU fishery of radio tagged fish were recorded by the data loggers positioned at the lower and upper ends of the fishery.

Table 1.-List of fates of radio-tagged chinook salmon in the Copper River, 1999.

Fate	Description
PU Mortality	A fish harvested in the PU fishery.
Sport Fish Mortality	A fish harvested in one of the sport fisheries.
Subsistence Mortality	A fish harvested in the subsistence fishery.
Spawner	A fish that migrated through the PU fishery and entered a spawning tributary of the Copper River.
Upstream Migrant	A fish that migrated upstream of the PU fishery, was never reported harvested, and was never located in a spawning tributary.
Radio Failure	A fish that was never recorded swimming upstream past the tagging site.

Test: There is no explicit test for this assumption. Recapture rates and transit times through the PU fishery for fish that continued their upstream migration quickly were compared to fish that were slow to continue their migration. Chinook salmon that continued their upstream migration quickly were thought to experience minimal handling affects and would behave similar to untagged fish.

Adjustment: If recapture rates and/or transit times of quick and slow-recovering fish differed, and if both groups had similar size distributions when released, abundance would be estimated without the slow-recovering fish. Then, the number of these fish released with marks would be added to the estimate. If quick and slow-recovering fish had dissimilar size distributions when released, the population would be stratified and the above procedure would be repeated for each group.

Tagged fish cannot lose their tags, and there can be no mortality of tagged fish between the tagging site and the PU fishery.

Design Considerations: The fates of all radio-tagged fish were identified relative to their entry into, harvest in, or passage through the PU fishery using the stationary tracking stations, aerial surveys, and tag return incentives.

Adjustment: Those fish that did not migrate into the PU fishery were not considered the experiment.

Marked fish mix completely with unmarked fish across the river.

Design Considerations: Because the nature of the capture method does not allow all fish to be either marked or examined for marks at the same probabilities, fish must mix across the river completely to allow for an unbiased estimate. To ensure data were collected to allow for a test of mixing, both banks of the river were sampled during both events. The bank of capture was recorded for all fish and was requested from PU fishers who returned tags.

Test: Recapture rates for fish marked on each bank were compared using contingency table analysis. The recapture matrix was inspected for sufficient numbers of fish moving across the river between marking and recapture. The assumption made was that if chinook salmon crossed-over between the marking and recovery sites, then fish that were not vulnerable to capture during the first sample (i.e. were migrating up the center of the channel outside of the drift areas), would become mixed with tagged fish in the PU fishery.

Adjustment: If there was no cross-over between sampling events, the estimate may be biased low if the unknown fraction of the population that migrated up the center of the river also did not mix with marked fish. If there was cross-over between sampling events, and if center-river fish mixed, but the marked fraction was different for the two banks, a geographically stratified estimator such as the method of Darroch (1961) would be used.

Fish have equal probabilities of being marked or equal probabilities of being recaptured regardless of their size or sex.

Design Considerations: Dip nets were selected as a capture gear because they capture a wide size-range of chinook salmon. Sex and length were recorded for all tagged fish during the first sampling event. A sample of (unmarked) fish captured in the PU fishery were measured for length and sex data.

Test: Size-selective sampling was investigated by testing cumulative length distributions of 1) all fish marked during the first sampling event; 2) tagged fish captured in the PU fishery; and, 3) all fish sampled in the PU fishery for homogeneity using twp Kolmogorov-Smirnov two-sample tests (one test compared groups 1 and 2 and the second test compared groups 1 and 3).

To test for sex-selective sampling, contingency table analysis was used to compare ratios of recaptured and not-recaptured fish for each gender.

Adjustment: If there were differences in the length compositions of marked and recaptured fish, the length corresponding to the maximum difference between the two distributions would be used as a break-point for stratification. If length compositions between marked and examined fish differed, then length composition for the population would be calculated from data collected during the second sample. If recapture rates differed by size class or by gender, both stratified and unstratified estimates of abundance would be calculated and compared to determine if the difference was meaningful.

Fish have equal probabilities of being marked regardless of time of capture, or marked fish have equal probabilities of being recaptured regardless of when they entered the fishery.

Design Considerations: Chinook salmon were marked over the span of the entire run expending near equal fishing effort at all times. All captured fish were tagged in a systematic manner. The date and time of capture were recorded for all fish.

Test: Contingency table analyses were used to compare recapture rates and marked:unmarked ratios in the second sample for weekly time intervals during the second sampling event.

Adjustment: If recapture rates and marked:unmarked ratios differed significantly over the various periods, a temporally stratified estimator such as the method of Darroch (1961) would be used to estimate abundance. Consecutive strata with similar recapture rates would be pooled. Stratified and unstratified estimates would be compared to determine if the difference was meaningful.

Estimator

A temporally stratified estimator using the method of Darroch (1961) was used to estimate abundance. The computer program SPAS (Arnason et al. 1996) was used to calculate the maximum-likelihood estimate and its associated variance. The estimate generated was germane to the point of entry into the PU fishery (prior to any inriver harvest). Because some chinook salmon were tagged and migrated through the PU fishery prior to its opening, the estimate only pertained to the period of time when the fishery was prosecuted (June 8-July 26). To calculate the total estimate of abundance, daily CPUE was summed for the period during the PU fishery (S_{PU}) and summed for the whole run (S_{total}). The proportion of the run that passed during the fishery was calculated as:

$$\hat{P}_{PU} = \frac{S_{PU}}{S_{total}}. \qquad (1)$$

The in-river abundance for the entire run was estimated as:

$$\hat{N}_{\text{total}} = \frac{\hat{N}_{\text{PU}}}{\hat{P}_{\text{PU}}}. \qquad (2)$$

Variance for $\hat{P}_{\text{PU}}$ was estimated by bootstrap methods (Efron and Tibshirani 1993). For each replicate, new separate samples for daily CPUE were drawn with replacement from periods in and out of the PU fishery. For 10,000 replicates, $\hat{P}_{\text{PU}}$ was calculated and the variance of $\hat{P}_{\text{PU}}$ was calculated as sample variance among replicates. The variance of $\hat{N}_{\text{total}}$ was estimated by the delta method (Seber 1982):

$$V\left[\hat{N}_{total}\right] = \left(\frac{1}{\hat{P}_{PU}}\right)^2 \left(V\left(\hat{N}_{total}\right)\right) + \left(\hat{N}_{total}\right)^2 \left(V\left(\frac{1}{\hat{P}_{PU}}\right)\right) + \left(V\left(\hat{N}_{total}\right)\right)\left(V\left(\frac{1}{\hat{P}_{PU}}\right)\right) \qquad (3)$$

where:

$$V\left(\frac{1}{\hat{P}_{PU}}\right) = \frac{1}{\hat{P}_{PU}{}^4} V\left(\hat{P}_{PU}\right). \qquad (4)$$

DISTRIBUTION OF SPAWNERS

All radio-tagged fish located in a spawning area ("spawner" fate in Table 1) were assigned to one of seven general areas: the Copper, Chitina, Tonsina, Klutina, Tazlina, and Gulkana rivers, and upper Copper drainage. The upper Copper drainage was defined as all tributaries upstream of the Gulkana River. Several radio-tagged fish migrated through the PU fishery and remained in the mainstem Copper River (generally between the Tonsina and Klutina rivers). It was assumed that most of these fish were spawning in this area, although no verification by ground surveys was conducted to validate this assumption. However, the following criteria were used to define fish located in this area as mainstem spawners:

1) A fish must have migrated at least 20 km upstream from the capture site;
2) A fish could not have previously migrated into a tributary stream and remained there for seven or more days.
3) A fish must have been located in the same general area at least two times over a two-week period.

The daily radio tagging rate and hours of fishing effort (h_i) in the test fishery varied by day. The count of fish tagged on day i having fate j (R_{ij}) was adjusted by dividing by h_i and the tagging rate $\left({x_i}/{X_i}\right)$ where x_i is the number of fish radio tagged and X_i is the total number of chinook salmon caught on day i. The adjusted count was

$$Y_{ij} = \left(\frac{X_i}{h_i x_i}\right) R_{ij}. \qquad (5)$$

Among fish that migrated past beyond the capture site, the proportion of fish that had fate j was estimated as

$$\hat{P}_j = \frac{\sum_{i}^{\text{days}} Y_{ij}}{\sum_{j}^{\text{fates}} \sum_{i}^{\text{days}} Y_{ij}}. \tag{6}$$

Variance was estimated using bootstrap techniques (Efron and Tibshirani 1993). From the data of fish caught on day *i*, a sample of size x_i was drawn with replacement. The new daily samples were combined to form a new sample for the season. From this resample data set, $\hat{P}_j$ was calculated for each of the fates (*j*). This process was repeated for 5,000 replicates. For a given fate *j*, the distribution of resample $\hat{P}_j$'s was normal. For fate *j*, the variance of $\hat{P}_j$ was estimated as the sample variance among the resample $\hat{P}_j$'s.

The same procedure was also used to determine the proportion of chinook salmon spawning in the nine index, aerial survey streams: the Little Tonsina River, Grayling Creek, St. Anne Creek, Manker Creek, Mendeltna Creek, Kiana Creek, Gulkana River, East Fork Chistochina River; and, Indian Creek. A chinook salmon was assigned to a index stream if the fish was located in that stream at least once during the aerial surveys.

MIGRATORY TIMING

Migratory timing patterns were described as time-density functions, where the relative abundance of a particular stock *t* that enters into the fishery during time interval *i* is considered discrete and is described by Mundy (1979) as:

$$f(t_i) = {}^{m_i}\!/_{m} \tag{7}$$

where:

$f(t_i)$ = the empirical probability distribution over the total span of the run for fish spawning in tributary *t*;

m = the total number of radio-tagged chinook salmon that ended up in tributary *t*; and,

m_i = the subset of m radio-tagged chinook salmon bound for tributary *t* that were caught and tagged during the i^{th} day.

For this analysis, stocks were defined as all chinook salmon spawning in the Copper, Chitina, Tonsina, Klutina, Tazlina, and Gulkana rivers, and the upper Copper River drainage. Those fish assigned a fate of spawner (Table 1) were used to determine the time-density functions.

The mean date of passage ($\bar{t}$) into the PU fishery for a spawning stock was defined as:

$$\bar{t} = \sum_{i=1}^{\ell} t_i f(t_i). \tag{8}$$

The variance about the mean was defined as:

$$s^2 = \sum_{i=1}^{\ell} (t_i - \bar{t})^2 f(t_i) \tag{9}$$

where:

t_i = time interval i;

ℓ = the number of time intervals (days) during the total span of the run.

Mean dates of passage for each of the spawning stocks were tested for homogeneity using Scheffè's multiple contrast test (Zar 1984).

Estimates of skewness or asymmetry (γ_1) and kurtosis or "peakedness" (γ_2) (Merritt and Roberson 1986) were:

$$\gamma_1 = \frac{\sum_{i=1}^{m} (t_i - \bar{t})^3 f(t_i)}{s^3}; \text{ and,} \tag{10}$$

$$\gamma_2 = \frac{\sum_{i=1}^{m} (t_i - \bar{t})^4 f(t_i)}{s^4}. \tag{11}$$

RESULTS

CAPTURE AND TAGGING

One thousand forty-five chinook salmon were captured between May 30 and July 31, 1999. Four hundred ninety-nine chinook salmon were fitted with only spaghetti tags, 522 were fitted with radio and spaghetti tags, and 24 were captured and released without marks. Largest daily CPUE of chinook salmon was 9.4 fish per hour on June 29 (Appendix A1). Although the daily tag application rate varied from 0.2 to 1.0, it generally approximated daily catches (Figure 3).

FATES OF RADIO TAGGED CHINOOK SALMON

Of the 522 chinook salmon fitted with radio tags, 508 migrated upstream past the capture site and were recorded by one or both of the downstream data loggers as moving into the PU fishery. Fourteen fish (2.7%) failed to migrate upstream beyond the capture site and either expelled tags, died from handling or natural causes, or migrated downstream to other areas. Ninety-two radio-tagged chinook salmon were harvested in the PU fishery. Eighty-eight of the harvested tags were returned by fishers. Four tagged fish were not reported by fishers, but were inferred harvested based on large signal strength recordings on the lower data logger, which indicated that the tag was removed from the water. A total of 416 tagged fish successfully passed through the PU fishery, and all were located at least one time above the fishery by one of the stationary data loggers or during an aerial tracking survey, or were harvested in sport or subsistence fisheries. Twenty-three fish that were known to have passed through the fishery were never reported as harvested or located in a spawning area (5.5% of tags that moved past the PU

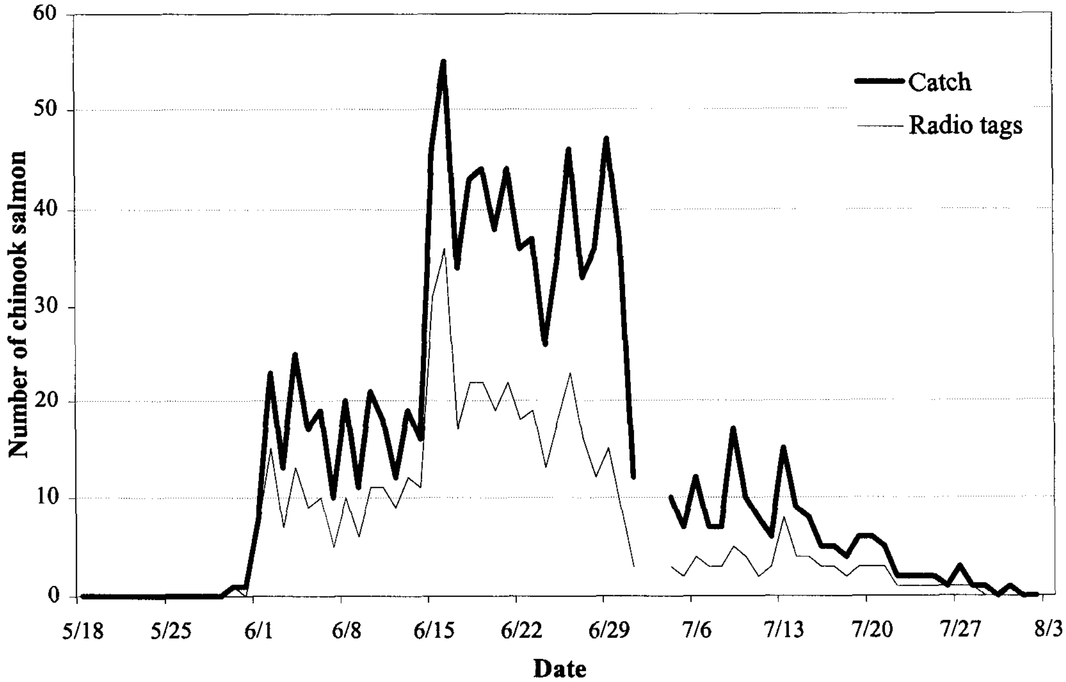

Figure 3.-Number of radio tags deployed each day and total daily catch of chinook salmon in the Copper River, 1999.

fishery). Thirty-eight tagged fish were harvested and returned by fishers in the subsistence fishery. Three hundred fifty-five tagged fish were documented in spawning areas, and 24 of these fish were harvested in sport fisheries (Table 2). Tracking stations were generally very efficient at detecting migrating chinook salmon (Table 3).

INRIVER ABUNDANCE

Tests of Consistency

Handling and marking chinook salmon did not appear to alter their probability of capture in the PU fishery. Information recorded on the two data loggers located just above the tagging site (at the lower boundary of the PU fishery) indicated that half of the fish moved from the release site to the lower boundary of the PU fishery in 2 days or less. However, 10% of the tagged fish took eight or more days to move into the fishery after tagging (Figure 4; top panel). One half of the tagged fish transited through the PU fishery in two and one-half days or less, and 95% of the fish passed through the PU fishery in six days or less (Figure 4; middle panel). A comparison of transit times for fish that exhibited minimal handling delay (less than 2 d) compared to those that exhibited moderate (2-7 d), and substantial (greater than 7 d) delays showed that average travel times were similar (F=2.85; df=341; P=0.06) for all three categories (Figure 4; bottom panel). Similarly, a comparison of recapture rates for fish that exhibited minimal handling delay compared to those that exhibited moderate and substantial delays showed that recapture rates were similar for all categories (χ^2=0.35; df=2; P=0.84; Table 4). These two tests suggested that any stress associated with handling was an immediate response and did not influence recapture probability or swimming speed through the fishery.

No tags were lost between marking and recapture in the PU fishery. Of the 522 chinook salmon released with radio tags, 14 never entered the PU fishery and were removed from the experiment. The remaining 508 tags were known to be either harvested in the PU fishery or successful migrants through the PU fishery.

More radio tags were recovered on the west bank during the second event than on the east bank reflecting the larger harvest that occurs on this bank (although no data were available regarding harvest by bank in the PU fishery, the west bank is adjacent to the road and typically has much greater effort than the east bank). Of the 230 fish marked on the west bank that migrated into the PU fishery, 28 were recaptured on the west bank and 5 were recaptured on the east bank. Of the 284 fish marked on the east bank that migrated into the PU fishery, 37 were recaptured on the west bank and 8 were recaptured on the east bank (Table 5). However, marked chinook salmon mixed with unmarked fish between banks (Table 6; χ^2=0.09, df=1, P=0.76), and recapture rates of fish marked on each bank were similar (Table 7; χ^2=0.15, df=1, P=0.70).

There was no significant size-selectivity of chinook salmon > 570 mm MEF using dip nets as a capture gear. Cumulative length distributions of fish marked during the first event and fish examined in the PU fishery were similar (DN=0.067; P=0.88). Cumulative length distributions of fish marked during the first event and fish recaptured in the PU fishery were statistically similar (DN=0.06; P=0.28), but showed a slightly greater selectivity for small (500-700 mm MEF) chinook salmon (Figure 5). The smallest chinook captured in the first event was 570 mm MEF, the smallest sampled in

Table 2.-Fates of radio-tagged chinook salmon in the Copper River, 1999.

Fate[a]	Number of Tags	
Total Deployed	522	
Radio Failure	14	
Total Entering PU	508	
PU Mortality	92	
Total Fish Passing through PU	416	
Upstream Migrant [b]	22	
Subsistence Mortality	38	
Spawner	356	
Sport Mortality		*24*

[a] Refer to Table 1 for definition of fates.

[b] Includes 12 tags that were recorded at the tracking station at the upper end of the PU fishery, but were never located again, and 11 tags that passed through the PU Fishery and drifted back downstream.

Table 3.-Efficiency of tracking stations in detecting passing radio-tagged chinook salmon in the Copper River, 1999.

Station	Total Tags Known to Pass Site[a]	Number Logged by Tracking Station	Station Efficiency	Number Located During Aerial Surveys	Aerial Tracking Efficiency
Upper Copper R.	44	40	90.9%	42	95.5%
Gulkana R.	42	41	97.6%	35	83.3%
Tazlina R.	12	12	100.0%	10	83.3%
Klutina R.	71	42	59.2%	66	93.0%
Tonsina R.	72	60	83.3%	69	95.8%
Chitina R.	78	76	97.4%	70	89.7%
Copper R.	368	362	98.4%		
Haley Cr. (both stations combined)	508	505	99.4%		

[a] Includes all fish logged by stations, located from aerial tracking surveys, and captured in the fisheries.

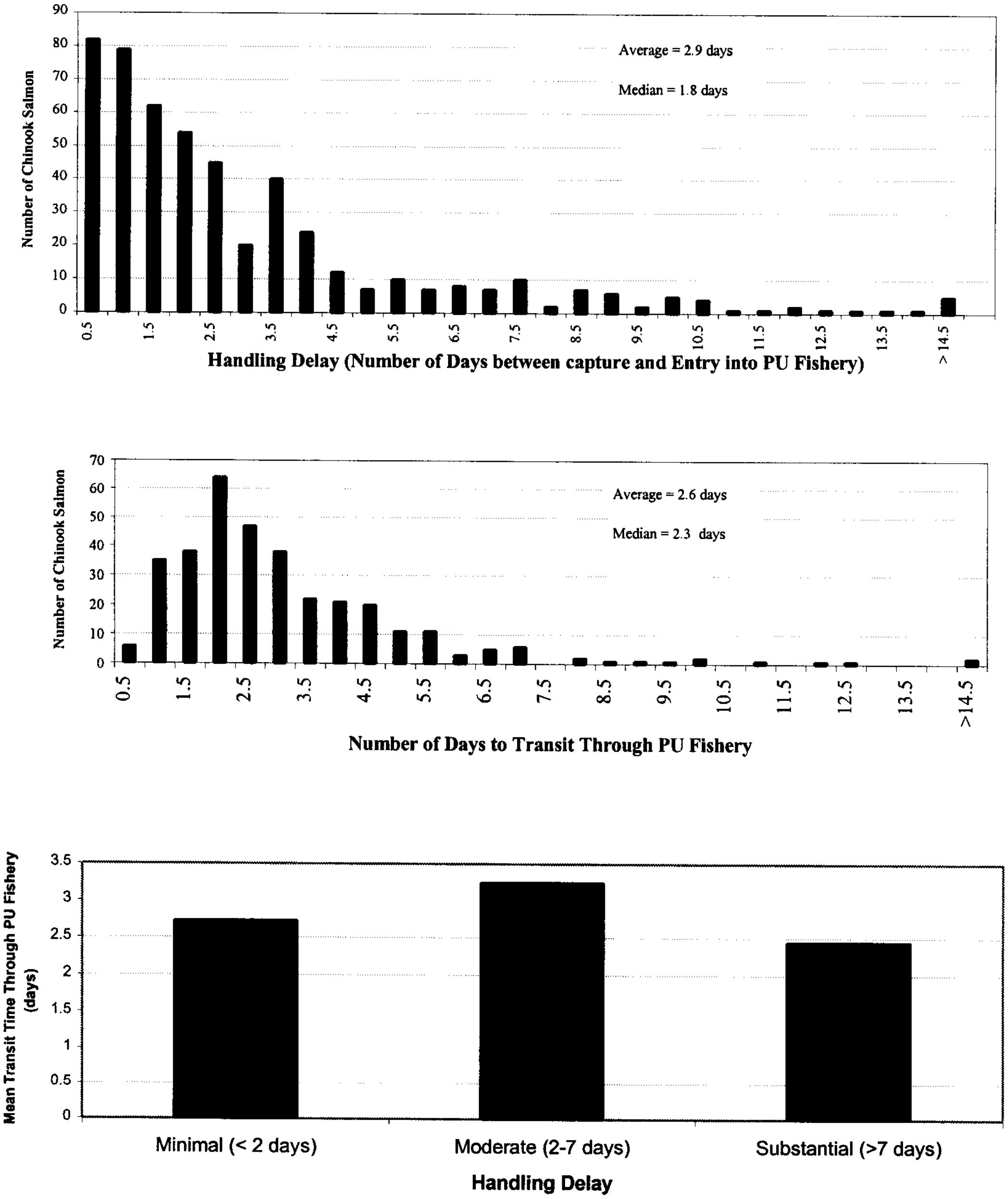

Figure 4.-Handling delay (top panel), transit times through the PU fishery (middle panel), and a comparison of mean transit times through the PU fishery of fish that exhibited minimal, moderate, and substantial handling delays (bottom panel) for radio-tagged chinook salmon in the Copper River, 1999.

Table 4.-Recapture rates for chinook salmon exhibiting minimal (<2 d), moderate (2-7 d), and substantial (>7 d) handling delays

	Handling Delay			
	< 2 days	2-7 days	> 7 days	Total
Recaptured	**51**	**33**	**8**	92
Not Recaptured	**225**	**146**	**45**	416
Total	276	179	53	508
Recapture Rate	0.18	0.18	0.15	0.18

χ^2=0.36; df=2; P=0.83 (for cells with bold numbers)

Table 5.-Capture histories for chinook salmon released on the east and west banks of the Copper River, 1999.

Capture History	Released West Bank	Released East Bank	Total
Total Marked	238	284	522
Malfunctions	8	6	14
Number Marked (entering PU)	230	278	508
Recaptured West Bank	28	37	65
Recaptured East Bank	5	8	13
Recaptured, but not known where	7	7	14
Total Recaptured	40	52	92
Number Not Recaptured	190	226	416
Recapture Rate	0.17	0.19	0.18

Table 6.-Number of chinook salmon captured on the west bank and on the east bank by bank of release and chi-square result of test comparing mixing rates across the river.

	Released West Bank	Released East Bank
Recaptured West Bank	28	37
Recaptured East Bank	5	8
$\chi^2 = 0.09$; df = 1; P = 0.76		

Table 7.-Number of chinook salmon recaptured and not recaptured by bank of release and chi-square result of test comparing recapture rates for fish marked on the east and west banks.

	Released West Bank	Released East Bank
Total Recaptured	40	52
Number Not Recaptured	190	226
$\chi^2 = 0.15$; df = 1; P = 0.70		

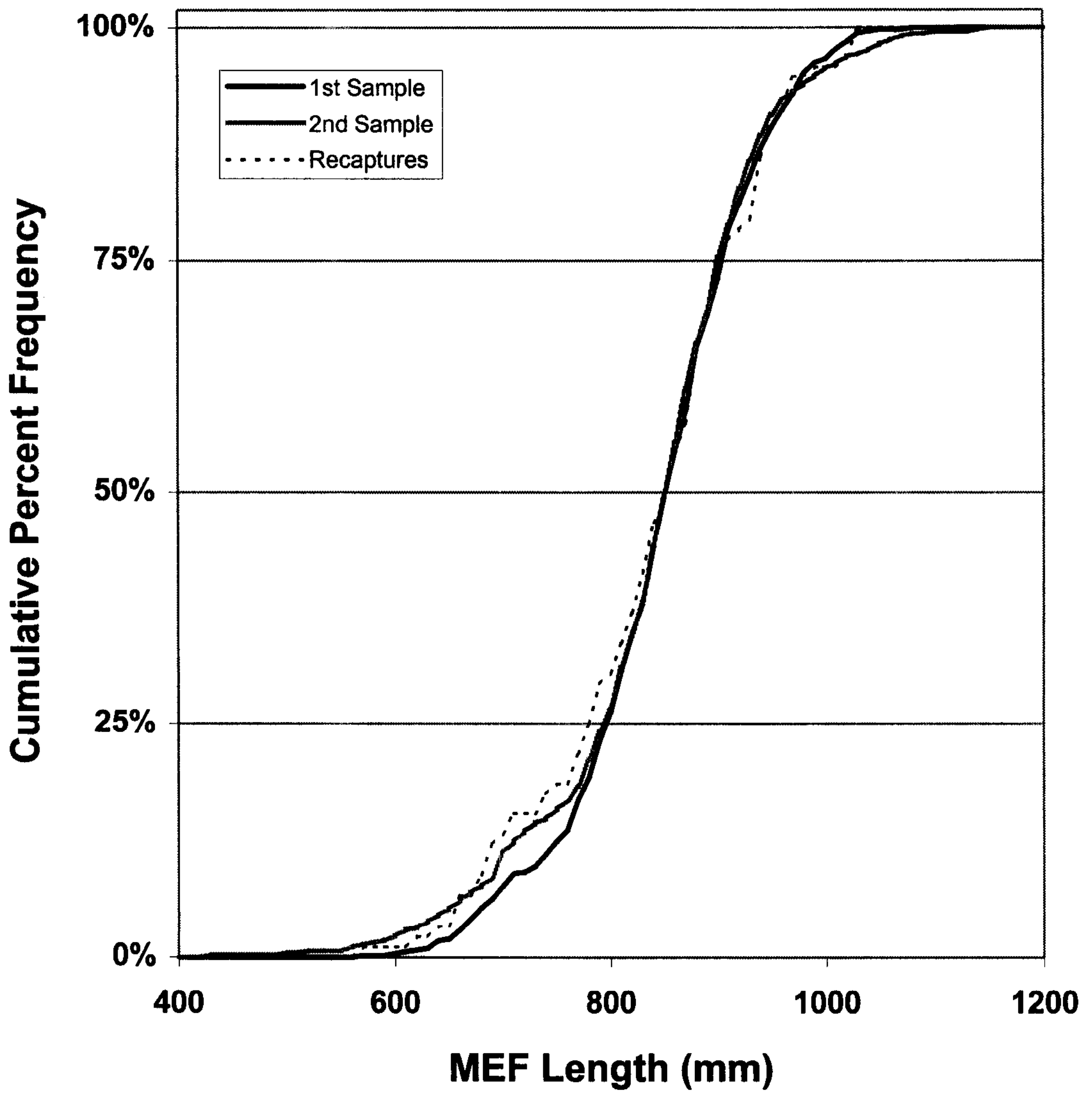

Figure 5.-Cumulative length frequency distributions for all fish captured during the first sample, all fish sampled in the PU fishery (second sample), and all tagged fish recaptured in the PU fishery, 1999.

the PU fishery was 424 mm MEF and the smallest recaptured was 570 mm MEF. Recapture rate of small chinook salmon (570-699 mm MEF), corresponding predominantly to age 4 (2 ocean years) was 0.34, while large, older chinook salmon (700-1,089 mm MEF) were recaptured at a rate of 0.17. Although these recapture rates are significantly different (χ^2=6.59; df=1; P=0.01), the difference in the estimate of abundance would be no more than 0.98% if adjustments through stratification of the data by size were ignored, owing to the fact that abundance of small chinook salmon was small (Table 8).

Recapture rates of males (0.21) and females (0.16) were different, but not significantly so (χ^2=1.81; df=1; P=0.18). Male to female ratios were 0.48 for tagged fish, 0.54 for recaptured fish, and 0.37 for fish sampled in the PU fishery. The difference between stratified and unstratified estimates of abundance was 3.3% (Table 9).

Age compositions of chinook salmon sampled in the test and PU fisheries were similar (χ^2=7.57; df=3; P=0.06) with age 1.3 (brood year 1994) dominating both samples (Tables 10 and 11).

Recapture rates varied over time in the PU fishery. The PU fishery opened on June 11 for 36 hours, again on June 19 for 36 hours, again on June 23 for 104 hours, again on June 30, and remained open thereafter until September 10. Five thousand seven hundred twenty-eight chinook salmon were reported harvested between June 11-July 26. Capture and recapture statistics were summarized by week (Tuesday-Monday) for all nine weeks in the experiment (Table 12). Recapture rates ranged from 0.00-0.31 over the nine weeks of the study. Because recapture rates were zero for the first and last weeks, these two weeks were not considered in estimation of abundance. Tests of consistency revealed that fish were recaptured at similar rates by week of tagging (test labeled "equal proportions" in SPAS program), but that marked to unmarked ratios in the PU harvest varied by week (test labeled "complete mixing" in SPAS program; Table 13). However, when consecutive weeks with similar recapture rates were pooled, significant test statistics were obtained for both tests (Table 14). The difference in stratified and unstratified estimates of abundance for the period June 8-July 26 was 7.5% (Table 15).

Abundance Estimate

The above tests of consistency detected only one meaningful source of bias, which was a result of variable probabilities of capture over time. To alleviate this bias, a stratified estimator using Darroch's (1961) method was used to estimate abundance. An estimated 28,810 (SE=3,311) chinook salmon >570 mm MEF passed through the PU fishery between June 8-July 26 (Table 15). Inspection of the relationship between mean weekly CPUE from the first sample and the corresponding weekly estimate of abundance showed that catchability coefficients were relatively consistent during the seven weeks of the experiment (Figure 6). Although recapture rates in the PU fishery varied by week, indicating that probabilities of capture varied during the first sample, the daily CPUE estimates included all chinook salmon captured, not just those that received radio tags. Because fishing effort was, for the most part, consistent over the experiment, and tagging rates varied over the experiment (Appendix A1), total daily catches were likely a more consistent index of daily passage than were total daily number of tags deployed.

Table 8.-Comparison of recapture rates for small and large chinook salmon and the percent difference between stratified and unstratified estimates.

	Small Salmon[a] (570-699 mm)	Large Salmon[b] (700-1,089 mm)	Total
Recaptured	**11**	**81**	92
Not Recaptured	**21**	**395**	416
	χ^2=6.09; df=1; P=0.01 (for cells with bold numbers)		
Total Marked	32	476	508
Recapture Rate	0.34	0.17	0.18
Examined in PU	42	403	445
Total Captured in PU[c]	541	5,187	5,728
$\hat{N}_{stratified}$ [d]	1,487	30,178	31,665
$\hat{N}_{unstratified}$ [d]			31,354
% Difference[e]			0.98%

a Salmon of this length range are predominately age 4 (2 ocean years).

b Salmon of this length range are predominately age 5-8 (3-6 ocean years).

c Because lengths of the entire PU harvest were not known, the values in this table were calculated by multiplying the proportion of each length class sampled in the PU by the total harvest.

d Calculated using the Chapman (1951) modified Petersen model (Seber 1982).

e Percent difference calculated as: $\%Difference = \left(\frac{\hat{N}_{strat} - \hat{N}_{unstrat}}{\hat{N}_{strat}}\right)100$.

Table 9.-Comparison of recapture rates for male and female chinook salmon and the percent difference between stratified and unstratified estimates.

	Males	Females	Total	M:F Ratio
Total Marked	242	262	504[a]	0.48
Recaptured	**50**	**42**	92	0.54
Not Recaptured	**192**	**220**	412	0.47
	χ^2 = 1.81; df = 1; P = 0.18 (for cells with bold numbers)			
Examined in PU Fishery	167	283	450	0.37
Estimated Catch in PU Fishery[b]	2,126	3,602	5,728	0.37
Recapture Rate	0.21	0.16	0.18	
$\hat{N}_{stratified}$ [c]	10,134	22,030	32,164	
$\hat{N}_{unstratified}$ [c]			31,108	
% Difference[d]			3.3%	

a Does not include four fish for which sex was not recorded.

b Because lengths of the entire PU fishery harvest were not known, the values in this table were calculated by multiplying the proportion of each length class sampled in the PU fishery by the total harvest.

c Calculated using the Chapman (1951) modified Petersen model (Seber 1982).

D Percent difference calculated as: $\%Difference = \left(\frac{\hat{N}_{strat} - \hat{N}_{unstrat}}{\hat{N}_{strat}} \right) 100$.

Table 10.-Age composition of chinook sampled in the test and personal use fisheries in the Copper River, 1999.

Brood Yr	1996	1995		1994	1993		1992	
Age[a]	1.1	0.3	1.2	1.3	1.4	2.3	1.5	Total Aged
				Test Fishery				
Female	0	1	16	300	82	4	0	403
Male	4	1	54	256	76	4	0	395
Total	4	2	70	556	158	8	0	798
				PU Fishery				
Female	1	0	14	98	22	1	1	137
Male	0	0	34	154	34	1	0	223
Total	1	0	48	252	56	2	1	360

[a] The notation x.x represents the number of annuli formed during river residence and ocean residence (i.e. and age of 2.4 represents two annuli formed during river residence and four annuli formed during ocean residence).

Table 11.-Numbers of chinook salmon captured in the test fishery and PU fishery by age and brood year and contingency table analysis comparing age composition.

Age[a]	3	4	5	6	7
Brood Yr	1996	1995	1994	1993	1992
Test Fishery	**4**	**72**	**556**	**166**	0
PU Fishery	**1**	**48**	**252**	**58**	1
χ^2=7.57; df=3; P=0.06 (for cells with bold numbers)					

[a] Age indicates years elapsed since brood year.

Table 12.-Capture histories for all radio-tagged chinook salmon and all chinook salmon harvested in the PU fishery in the Copper River, 1999. Cells with bold numbers indicate data used for the mark-recapture experiment.

Week of Entry Into PU Fishery	Week of Recapture[a] 1	2	3	4	5	6	7	8	9	Number Recaptured	Number Marked	Number not Recaptured	Recapture Rate
1 (June 1-June 7)	0				1					1	61	60	0.02
2 (June 8-June 14)		**4**								**4**	**36**	**32**	0.11
3 (June 15-June 21)			**11**	**3**		**1**				**15**	**109**	**94**	0.14
4 (June 22-June 28)				**42**	**1**	**1**				**44**	**178**	**134**	0.25
5 (June 29-July 5)					**13**					**13**	**54**	**41**	0.24
6 (July 6-July 12)						**2**		**1**		**3**	**16**	**13**	0.19
7 (July 13-July 19)							**4**			**4**	**23**	**19**	0.17
8 (July 20-July 26)								**8**		**8**	**26**	**18**	0.31
9 (July 27-Aug 3)									0	0	5	5	0.00
Total Recaptured	0	4	11	45	15	4	4	9	0	92	508	416	0.18
Recaptures Used for Estimate		**4**	**11**	**45**	**14**	**4**	**4**	**9**		**91**	**442**	**351**	0.21
Number Unmarked Caught in PU Fishery	0	362	695	2,057	1,144	585	394	206	99				
Number Used for Estimate		362	695	2,057	1,143	585	394	206					
Total Number Caught in PU Fishery	0	366	706	2,102	1,158	589	398	215	99				
Marked:Unmarked	0.00	0.01	0.02	0.02	0.01	0.01	0.01	0.04	0.00				

[a] Week of recapture same as week of entry into PU fishery. Weeks ran from Tuesday-Monday.

Table 13.-Contingency table analyses comparing marked:unmarked and recaptured:not-recaptured ratios during weekly periods for radio-tagged chinook salmon in the Copper River, 1999.

	June 1-7	June 8-14	June 15-21	June 22-28	June 29-July 5	July 6-12	July 13-19	July 20-26	July 27-Aug 2
Test for Equal Marked:Unmarked Ratios in the Second Sample ("complete mixing" test)									
Marked	0	**4**	**11**	**45**	**15**	**4**	**4**	**9**	0
Unmarked	0	**362**	**695**	**2,057**	**1,143**	**585**	**394**	**206**	99
Marked:Unmarked	0.000	0.011	0.016	0.022	0.013	0.007	0.010	0.044	0.000
χ^2=17.58; df=6; P=0.007(for cells with bold numbers)									
Test for Equal Recaptured:Not-Recaptured Ratios in the Second Sample ("equal proportions" test)									
Recaptured	1	**4**	**15**	**44**	**13**	**3**	**4**	**8**	0
Not Recaptured	60	**32**	**94**	**134**	**41**	**13**	**19**	**18**	5
Recapture Rate	0.016	0.111	0.138	0.247	0.241	0.188	0.174	0.308	0.000
χ^2=9.17; df=6; P=0.164 (for cells with bold numbers)									

Table 14.-Contingency table analyses comparing marked:unmarked and recaptured:not-recaptured ratios for weeks with similar recapture rates pooled for radio-tagged chinook salmon in the Copper River, 1999.

	June 1-7	June 8-21	June 22-July 5	July 6- 19	July 20-26	July 27-Aug 2
Test for Equal Marked:Unmarked Ratios in the Second Sample						
("complete mixing" test)						
Marked	0	**15**	**60**	**8**	**9**	0
Unmarked	0	**1,057**	**3,200**	**979**	**206**	99
Marked:Unmarked	0.000	0.014	0.019	0.008	0.044	0.000
χ^2=13.84; df=3; P=0.003 (for cells with bold numbers)						
Test for Equal Recaptured:Not-Recaptured Ratios in the Second Sample						
("equal proportions" test)						
Recaptured	1	**19**	**57**	**7**	**8**	0
Not Recaptured	60	**126**	**175**	**32**	**18**	5
Recapture Rate	0.016	0.131	0.246	0.179	0.308	0.000
χ^2=9.03; df=3; P=0.029 (for cells with bold numbers)						

Table 15.-Estimated abundance of chinook salmon entering into the PU fishery in the Copper River from June 8-July 26, 1999, and the percent difference between stratified and unstratified estimates.

			P(Capture)	Recovery Strata			
Marking Strata	Abundance	SE	First Event	June 8-June 21	June 22-July 5	July 6-July 19	July 20-July 26
June 8-June 21	10,363	2,657	0.014	9,071	865	426	0
June 22-July 5	12,617	1,751	0.018	0	12,293	324	0
July 6-July 19	5,597	2,353	0.007	0	0	5,131	466
July 20-July 26	232	510	0.112	0	0	0	232
Total	28,810	3,311		9,071	13,159	5,881	699
P(Capture) Second Event				0.118	0.248	0.168	0.308

	Abundance				Total		
	June 8-June 21	June 22-July 5	July 6-July 19	July 20-July 26	Abundance	SE	CV
$\hat{N}_{stratified}$ [a]	9,071	13,159	5,881	699	28,810	3,311	0.115
$\hat{N}_{unstratified}$ [b]					26,651	2,440	0.092
% Difference[c]					7.5%		

[a] Calculated using the method of Darroch (1961).

[b] Calculated using the Chapman (1951) modified Petersen model (Seber 1982).

[c] Percent difference calculated as: $\%Difference = \left(\frac{\hat{N}_{strat} - \hat{N}_{unstrat}}{\hat{N}_{strat}} \right) 100$.

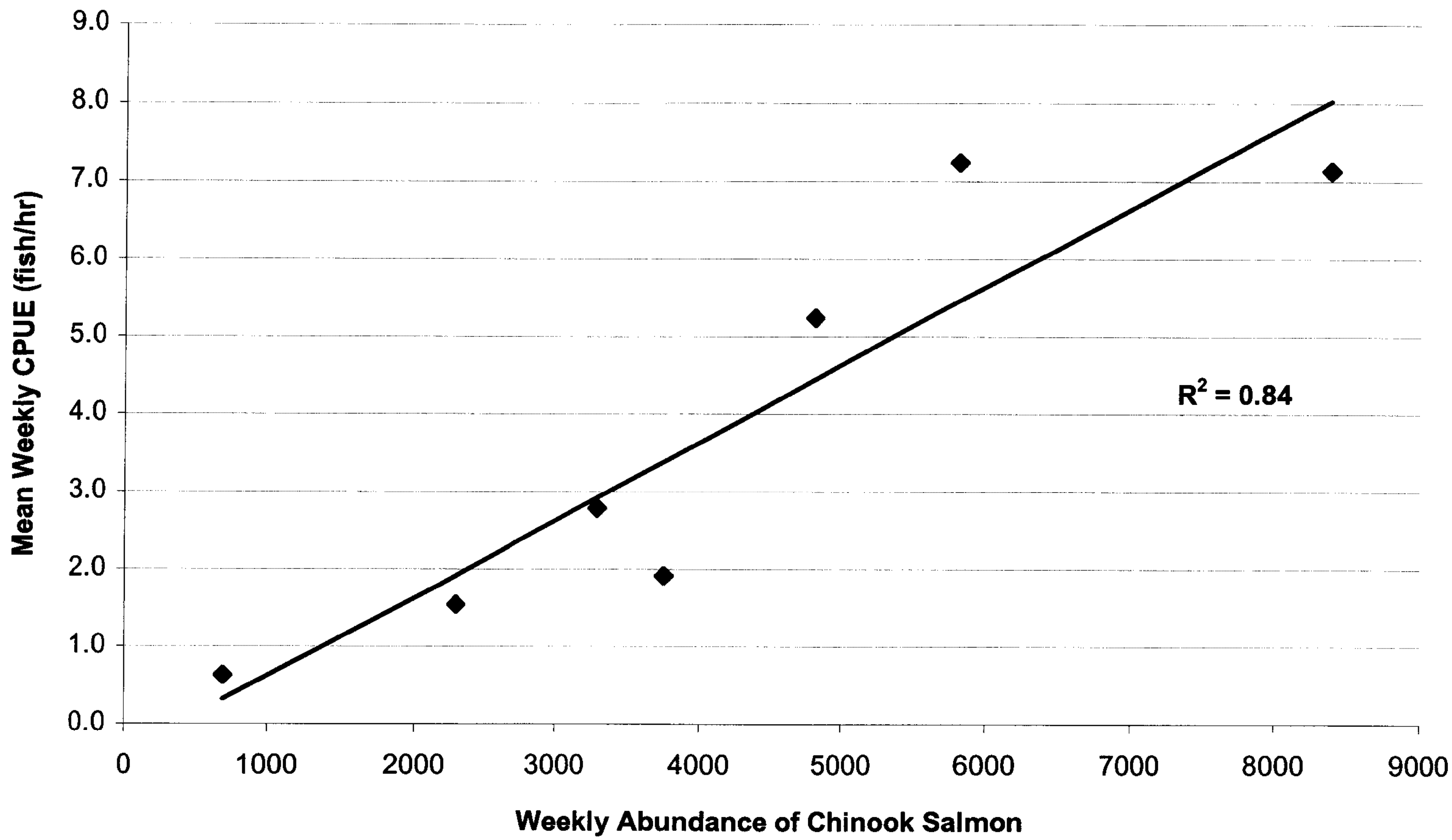

Figure 6.-Comparison of mean weekly CPUE and weekly abundance of chinook salmon during the mark-recapture experiment in the Copper River, 1999.

Therefore, to obtain an estimate of total abundance, the estimate for the seven-week period was expanded to include fish that passed through the fishery before and after this period based on CPUE information from the first (marking) sample. The proportion of the CPUE curve corresponding to the period June 8-July 26 was 0.898 (SE=0.0272; Figure 7). Total abundance, estimated by dividing the Darroch estimate by this proportion, was 32,090 (SE=3,814) chinook salmon.

SPAWNING DISTRIBUTION

Radio-tagged chinook salmon were located in all of the major drainages (Table 16). The smallest proportion returned to the Tazlina River drainage (0.030; SE=0.021), and the largest proportion returned to the Klutina River drainage (0.237; SE=0.021). The lower portion of the Copper River drainage, including the Chitina, Tonsina, Klutina, and mainstem Copper rivers, accounted 0.761 of the returning fish. The nine aerial survey index streams accounted for 0.241 (SE=0.019) of all chinook salmon migrating into tributary streams (Table 17). The Gulkana River accounted for 0.474 of fish located in the nine streams. During aerial survey flights, chinook salmon were located in 35 different tributary streams (Table 18). Mainstem spawners accounted for 0.788 (SE=0.032) and 0.761 (SE=0.037) of all spawning chinook salmon in the Tonsina and Klutina rivers, respectively (Table 19).

MIGRATORY TIMING

Migratory time-density functions at the capture site varied among the major spawning stocks (Figure 8). Timing curves for all stocks were generally skewed right and showed leptokurtosis. Mean date of passage ranged from June 10 for chinook salmon bound for the upper Copper River drainage to July 4 for fish bound for the mainstem Klutina River (Table 20). Migratory timing of chinook salmon bound for tributaries in the Tonsina and Klutina rivers was generally earlier than their mainstem spawning counterparts (Figure 9). Comparison of migratory timing for nine spawning stocks indicated three groups of spawning stocks with similar mean dates of passage (Figure 10).

DISCUSSION

All potential sources of bias to the abundance estimate for which data were available for tests were found to be either negligible or were addressed through use of a stratified estimator. However, because the second sample was collected and recorded by the public, there are potential sources of error that could not be explicitly tested for that warrant discussion. These potential sources of bias include misreporting harvest, non-reporting of captured tags, and selection for tagged fish.

Misreporting harvest could bias the abundance estimate either high or low depending on whether people reported harvesting more chinook salmon than they actually took (biases the estimate high), or more likely, if people reported fewer chinook salmon than were actually harvested (biases the estimate low). The extent to which misreporting harvest occurred is unknown, but the associated bias would be approximately equal to the percentage of the unreported harvest (by persons returning permits) to the total reported harvest. For example, if 281 chinook salmon (5% of total reported harvest) were harvested and not reported, the estimate of abundance would be biased low by 5%. Unless the magnitude of the unreported harvest by persons returning permits is large, the

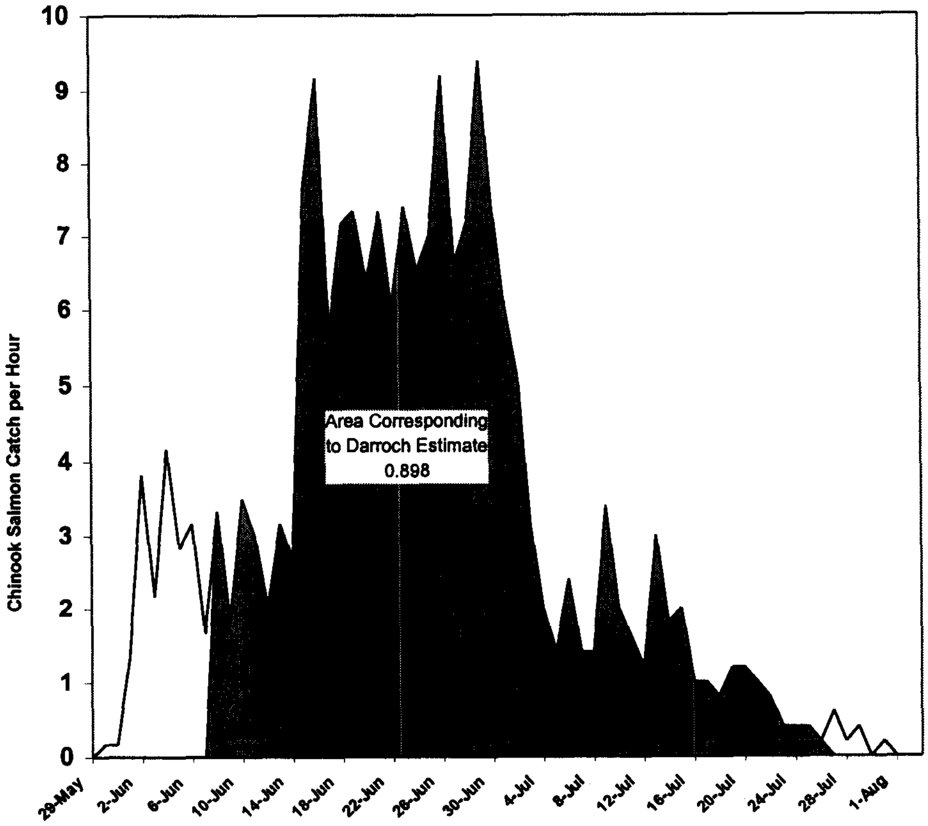

Figure 7.-Catch per unit effort of chinook salmon during the first sample of the mark-recapture experiment and the proportion of the total catch (shaded) corresponding to the period of the abundance estimate.

Table 16.-Distribution of radio-tagged chinook salmon in major spawning drainages in the Copper River, 1999.

Spawning Stream	Number of Radio Tags	Adjusted Number of Radio Tags[a]	Proportion of all Spawners	SE
Chitina River	78	150.6	0.20	0.02
Mainstem Copper	36	80.2	0.10	0.01
Tonsina River	72	171.4	0.22	0.01
Klutina River	72	182.2	0.24	0.02
Tazlina River	12	23.3	0.03	0.02
Gulkana River	42	88.2	0.12	0.01
Upper Copper River tributaries	44	73.5	0.10	0.01
Total	356	769.3	1.00	

[a] Adjusted for daily tagging rates and fishing effort.

Table 17.-Proportions of radio-tagged chinook salmon located in nine aerial survey index streams in the Copper River drainage, 1999.

Spawning Stream	Number of Radio Tags	Adjusted Number of Radio Tags [a]	Proportion of all Spawners	SE
Indian Creek	2	3.4	0.004	0.003
E. Fk Chistochina River	10	16.5	0.021	0.006
Gulkana River	42	88.2	0.114	0.014
Mendeltna Creek	4	7.9	0.010	0.005
Kiana Creek	5	9.0	0.012	0.009
St. Anne Creek	3	5.3	0.007	0.004
Manker Creek	13	26.4	0.034	0.009
Greyling Creek	8	15.1	0.020	0.006
L. Tonsina River	7	14.2	0.018	0.007
Total in Index Streams	**94**	**186.0**	**0.241**	**0.019**
Other Areas	262	583.3	0.758	0.019
Total in All Streams	356	769.3	1.000	

[a] Adjusted for daily tagging rates and fishing effort.

Table 18.-Numbers of radio-tagged chinook salmon located in tributaries of the Copper River during aerial tracking surveys, 1999.

Tributary	Number
Upper Copper River Drainage	
Ahtell River	2
Bone Creek	1
Chistochina River (mainstem)	2
E. Fork Chistochina River	6
No Name (south of E. Fork Chistochina River)	2
Sinona Creek	2
Gakona River (mainstem)	4
Spring Creek	2
No Name (opposite Spring Creek)	2
Indian River	2
Drop Creek	3
No Name (east side opposite Indian River)	2
No Name (east side opposite Sinona Creek)	1
No Name (east side near Yokneda Lakes)	1
Gulkana River Drainage	
Gulkana River (mainstem)	14
Middle Fork Gulkana River	3
West Fork Gulkana River	3
Hungry Hollow Creek	1
Paxson Lake Outlet	1
Tazlina River Drainage	
Kiana Creek	5
Mendeltna Creek	4
Klutina River Drainage	
Klutina River (mainstem)	46
Manker Creek	13
St. Anne Creek	3
Tonsina River Drainage	
Tonsina River (mainstem)	51
Greyling Creek	8
Little Tonsina River	7
Dust Creek	1
Bernard Creek	1

-continued-

Table 18.-Page 2 of 2.

Tributary	Number
Chitina River Drainage	
Chakina River	12
Gilahina River	3
Lakina River	3
Monahan Creek	2
Tana River	6
Tebay River	35

Table 19.-Proportion of mainstem and tributary spawning in the Tonsina and Klutina rivers, 1999.

River	Number of Radio Tags	Adjusted Number of Radio Tags[a]	Proportion of all Spawners	SE
Tonsina River				
Mainstem	54	132.9	0.79	0.03
Greyling Creek	8	15.4	0.09	0.02
L. Tonsina River	7	14.7	0.09	0.02
Total in Index Streams[b]	15	30.1	0.18	0.03
Bernard Creek	1	1.5	0.01	0.01
Dust Creek	2	4.1	0.02	0.01
Total in all Tributaries	18	35.7	0.21	0.03
Total	72	168.6	1.00	0.00
Klutina River				
Mainstem	34	101.7	0.76	0.04
Manker Creek	13	26.8	0.20	0.04
St. Anne Creek	3	5.2	0.04	0.02
Total in Index Streams[b]	16	32.0	0.24	0.04
Total	50	133.7	1.00	0.00

[a] Adjusted for daily tagging rates and fishing effort.

[b] Index streams refer to the two tributaries in each drainage (listed above the footnote reference) for which aerial survey counts are conducted.

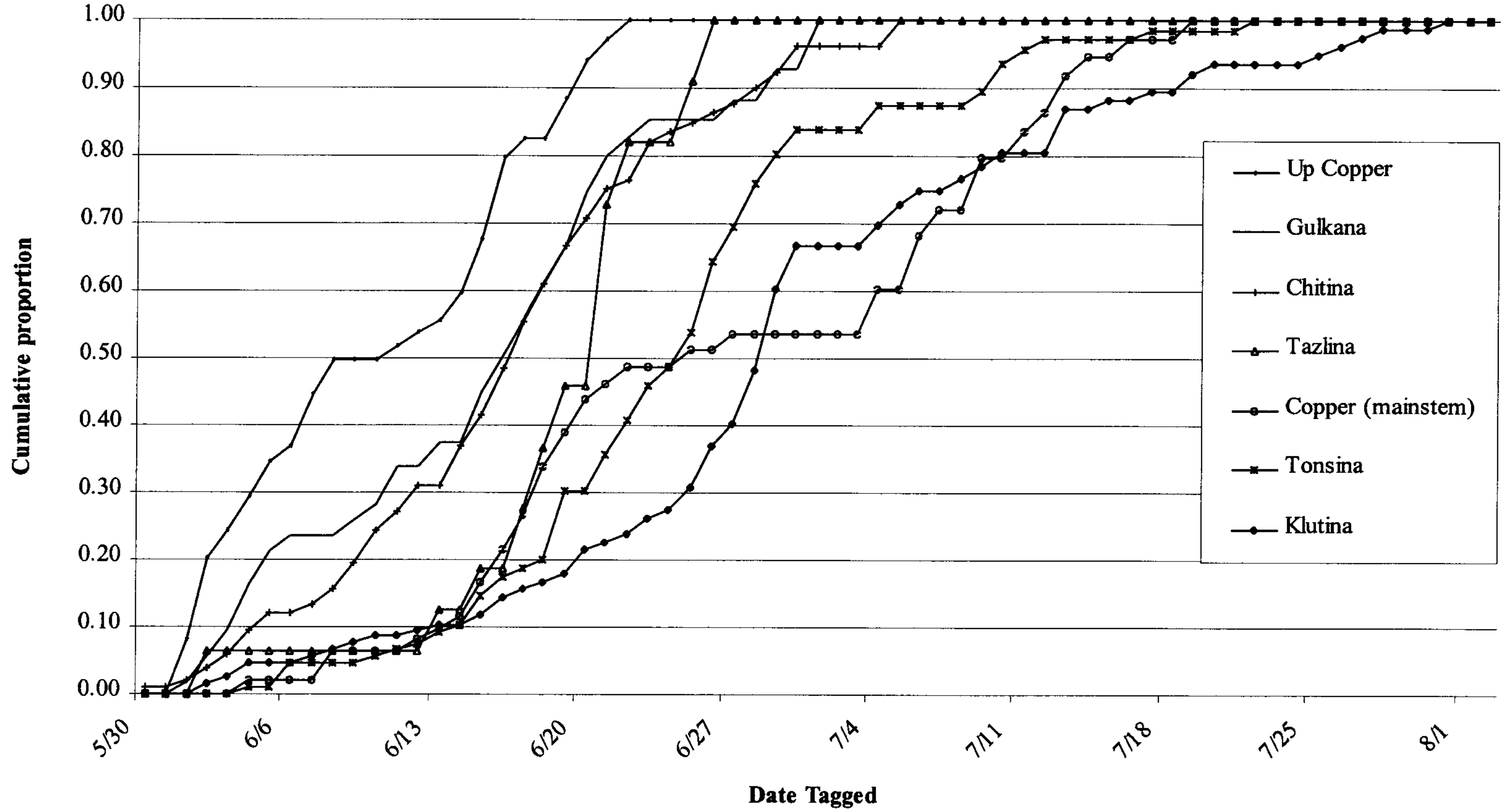

Figure 8.-Migratory-timing profiles at the capture site for the major spawning stocks of chinook salmon in the Copper River, 1999.

Table 20.-Statistics regarding the migratory timing of the major chinook salmon spawning stocks in the Copper River, 1999.

Spawning Stock	Duration (Days)	Mean ($\bar{t}$)	s^2	Skewness[a] (γ_1)	Kurtosis[a] (γ_2)
Upper Copper River	06/01-06/22 (22)	06/10	47.44	39.2	174
Gulkana River	06/01-07/01 (31)	06/15	72.78	11.5	36
Chitina River	05/30-07/05 (37)	06/16	67.13	11.3	35
Tazlina River	06/06-06/26 (21)	06/19	31.47	25.5	111
Klutina River (All)	06/02-07/31 (60)	06/29	168.16	-0.4	1
Mainstem	06/15-07/31 (47)	07/04	124.80	16.7	59
Tributaries	06/02-06/26 (25)	06/15	54.97	-2.6	5
Tonsina River (All)	06/04-07/22 (49)	06/24	85.73	1.7	6
Mainstem	06/11-07/22 (42)	06/26	78.29	23.2	93
Tributaries	06/04-06/25 (21)	06/17	40.28	0.6	6
Mainstem Copper River	06/04-07/19 (46)	06/27	151.34	0.03	2

[a] In a normal frequency distribution γ_1 and γ_2 are both zero. A negative γ_1 indicates skewness to the left; a positive γ_1, skewness to the right. A negative γ_2 indicates platykurtosis, and a posive γ_2 shows leptokurtosis.

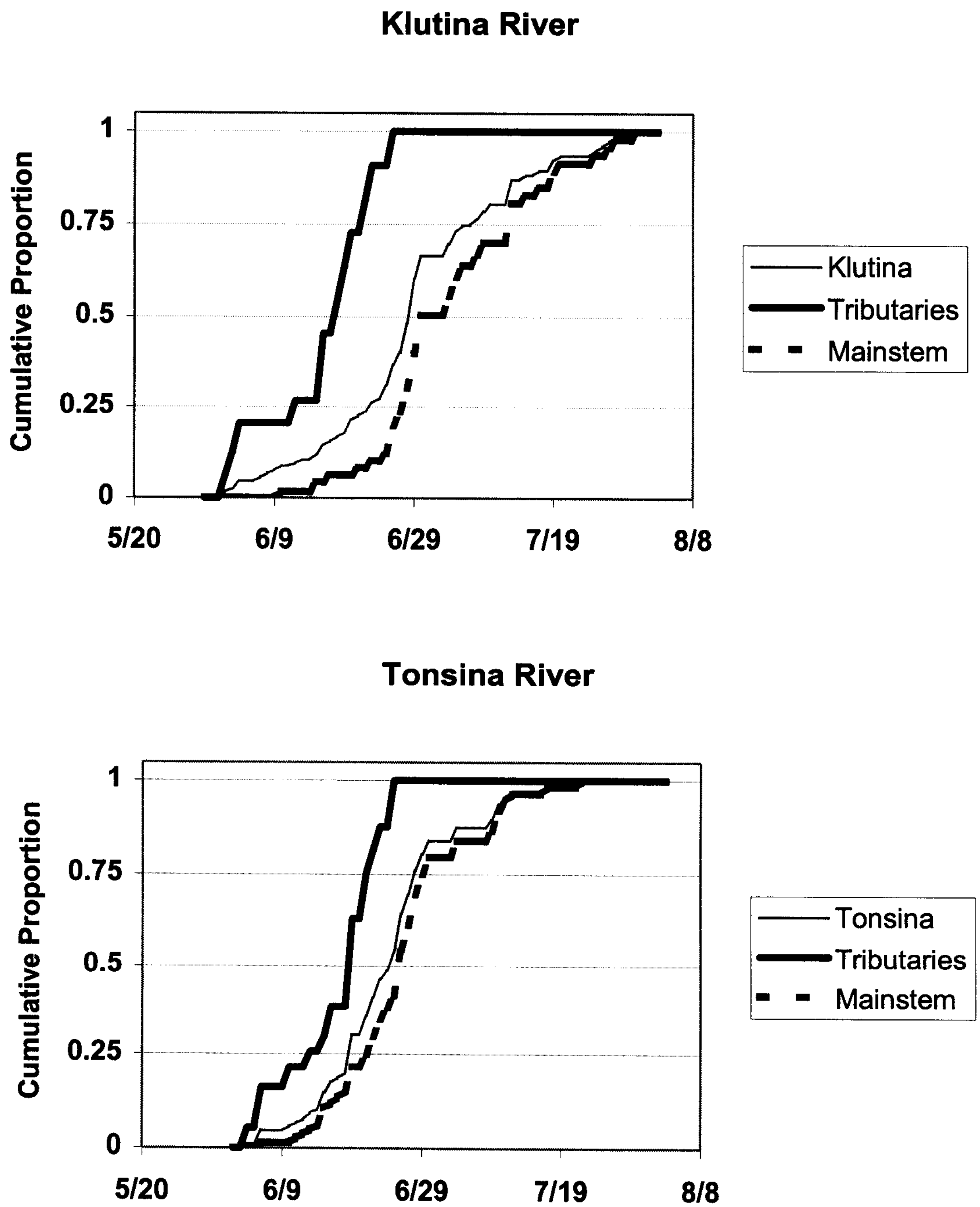

Figure 9.-Migratory-timing profiles of chinook salmon in the Klutina and Tonsina rivers comparing timing of tributary and mainstem spawners.

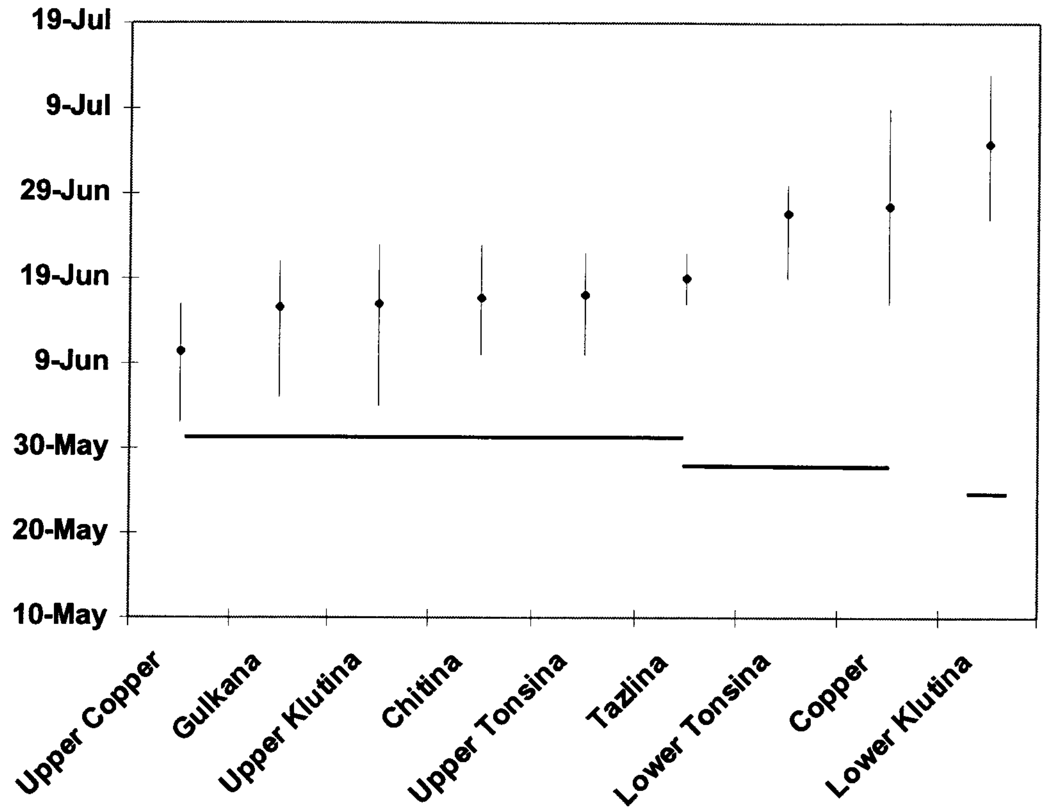

Figure 10.-Mean passage date (symbol) and 80% range (vertical lines) of Copper River chinook salmon stocks at the capture site in 1999. Horizontal lines indicate groups of stocks with similar mean passage dates.

bias to the abundance estimate is small. Harvest of chinook salmon by persons who fished illegally (i.e. did not obtain or return a permit) is only of consequence to the estimate if a tagged fish was captured. Tagged fish are used in the estimation whether they were reported or not reported, whereas unmarked fish that are not reported are not. The bias associated with illegal, or unreported harvest that include tagged fish is negative. Non-reporting of harvested tags likely did not bias the estimate of abundance unless the tagged fish were associated with unreported harvest as discussed above. The tracking stations located at the upper and lower boundaries of the fishery were able to detect all tagged fish entering and exiting the fishery. Because the fates of all tagged fish were known relative to their migration through, or harvest in the PU fishery, we were able to treat the harvest in the PU fishery as the second sample without examining fish to estimate marked to unmarked ratio. Nearly all tags (88 of 92) from chinook salmon harvested in the PU fishery were returned voluntarily by fishers. Four tags were inferred as harvested based on large signal strength recordings on the lower data logger indicating that the tag was removed from the water, and also from the fact that these four tags were never located by upstream data loggers or during aerial tracking surveys.

Selection for tagged fish by participants in the PU fishery in response to the $200 tag return lottery reward was not apparent. An analysis of bag limits of chinook salmon in the PU fishery during 1999 indicated that only 15% of all permit holders who harvested chinook salmon filled their bag limit of four (T. Taube, Alaska Department of Fish and Game, Glennallen, personal communication). It is not likely that persons who had not filled their bag limit would release a captured chinook salmon in attempt to catch a tagged fish for a chance to win $200. The lottery reward was established to encourage return of tags, and was chosen over a flat fee reward for all returned tags to minimize selection for tags. The incentive to return tags to enter the lottery was not sufficient enough to encourage three fishers to return the tags, but they did contact the staff to declare that they had caught a tagged fish but would not return it. If tags were being selected for, the inflated marked-to-unmarked ratio would bias the abundance estimate low. Given the success of the tracking stations at detecting all tagged fish migrating into and out of the fishery, the lottery reward will not be continued in future studies.

Selection for large fish in response to a fishing derby offering $10,000 for the largest chinook salmon captured[2] was also not apparent. A total of 27 derby tickets were purchased and four fish were entered for prizes (unpublished information from Alaska Department of Revenue-Gaming Unit and Ahtna, Inc.). Comparison of length frequency distributions of fish marked in the test fishery and fish captured in the PU fishery also did not suggest selectivity for large fish in the fishery (see Figure 5).

Use of radio tags as the primary mark allowed for explicit testing of certain assumptions that is not possible with conventional tagging methods. Given that the fate of all tags relative to their migration into, harvest in, or migration through the PU fishery was known, tag loss, emigration, and mortality were known with certainty and those tags were removed from the experiment. The 14 tagged fish that never entered the PU fishery were likely a combination of fish that had regurgitated tags and fish that retained their tag, but migrated downstream either by natural behavior, or because of handling stress.

[2] The derby also offered a second place prize of $3,500.00 and a third place prize of $1,500.00.

Downstream retreat of tagged fish has been noted in several studies (Burger et al. 1984, Eiler et al. 1991, Bendock and Alexandersdottir 1992, and Pahlke and Bernard 1996). If downstream movement is handling induced, and not natural behavior, marked fish would be less likely to be captured in the second event than unmarked fish and the estimate of abundance would be biased high. Whether natural or handling induced behavior, downstream retreat is of no consequence to the estimate when these fish are censored from the experiment.

Fates of chinook salmon tagged with only spaghetti tags, other than those harvested in the PU fishery, were not known. Of the 1,045 chinook salmon captured, 499 were marked with only a spaghetti tag. Sixty-seven (13%) of these fish were known to be harvested in the PU fishery from tag returns (Appendix B). This is a slightly lower recovery rate than what was observed for the radio-tagged fish (18%). Estimated abundance calculated from spaghetti-tagged-only fish[3] was 18% higher than the estimate using radio-tagged fish. However, based on observations of radio-tagged fish, it is likely that this estimate is biased high as a result of mortality, emigration or tag loss of marked fish between sampling events as well as from non-reporting of harvested tags. Consequently, spaghetti-tagged only fish were not used to estimate abundance. Loss of spaghetti tags ranged from 23%-38% during mark-recapture experiments on the Taku River (Pahlke and Bernard 1996). In this study we could not explicitly estimate rate of tag loss of spaghetti-tagged fish because many fishers returned only the radio tag and did not leave a contact address or phone number.

Aerial-survey counts of nine spawning streams, which have traditionally been used to evaluate escapement, likely do not provide a reliable and consistent measure of total drainage escapement. The largest escapements of chinook salmon in this study were noted in the downriver tributaries, especially the Klutina and Tonsina rivers. Within these two rivers, most spawning occurred in the mainstem portions, which are glacially occluded and difficult to assess with aerial survey counts. In fact, most of the escapement in the Copper River drainage was noted in systems that either are too turbid to visually count fish, or in numerous small order tributaries that support very few spawning chinook salmon. The nine aerial survey index streams that are normally surveyed accounted for only one quarter of the total escapement. Of these nine streams, the Gulkana River accounted for approximately half of the escapement, while it represented only 11.5% of the total drainage escapement. There were distinct differences in run timing past the capture site among the various spawning stocks which implies that each could be subjected to varying exploitation rates in the mixed stock fisheries (commercial, PU, and subsistence). Therefore, the distribution of the escapement throughout the drainage likely varies from one year to the next. The aerial survey counts do not include the late-run stocks such as the mainstem Klutina and Tonsina rivers, which in 1999 accounted for a significant portion of the total escapement.

Our radio-tagging data suggested that upriver stocks tended to enter the river earlier than downriver stocks. Entry patterns such as this have been documented in other large river systems (Koski et al. 1994, Pahlke and Bernard 1996, and McPherson et al. 1997). The differences in run timing observed between tributary and mainstem spawners in the

---

[3] Based on a pooled Petersen estimator for the period June 8-July 26.

Klutina and Tonsina rivers are analogous to the early and late run stocks on the Kenai River (Burger et al. 1985). The late run stocks in the Kenai River spawn in tributaries with effluent from large lakes (Kenai and Skilak lakes), whereas early-run stocks spawn in run-off tributaries. Both the mainstem Klutina and Tonsina rivers originate from large lakes (Klutina and Tonsina lakes), while tributaries are run-off streams. Burger et al. (1985) hypothesized that these behavioral differences in run timing are a result of warmer water temperatures in the lake-fed tributaries, which enable eggs to incubate faster than in the cooler run-off tributaries.

Approximately 10% of the radio tags assigned a spawner fate were located in the mainstem Copper River between the Klutina and Tonsina rivers. These fish were assigned a spawner fate if they had migrated at least 20 km from the capture site, had been located in the same general area at least two times over a two week period, and had not previously migrated into a tributary stream and remained there for seven or more days. References to chinook salmon spawning in mainstem, glacial rivers are sparse. Koski et al. (1993) noted radio-tagged chinook salmon in the mainstem Nass River that were believed to be spawning, and at least one spawning area in the mainstem Taku River was documented (J. Eiler, NMFS, Auke Bay, personal communication). Chinook salmon are known to spawn in the Kenai River (Burger et al. 1984) and in the Tonsina and Klutina rivers (this study), which are glacial in origin. However, these three systems are all buffered by large lakes that reduce the turbidity and extreme summer flows that occur in the mainstem river. The chinook salmon assumed to be spawning in the mainstem river may have been fish that failed to complete their upstream migration, either from natural causes or as a result of handling. Gray and Haynes (1979) found that percent return (to spawning grounds) of chinook salmon fitted with internal radio tags was significantly less than control fish, which were fitted with spaghetti tags only. Future studies should attempt to validate mainstem spawning with ground-based tracking.

ACKNOWLEDGEMENTS

Our thanks to the field personnel, Ron Burr, John Chythlook, Doug Edwards, Ted Lambert, Rick Queen, James Savereide, Brendan Scanlon, Corey Schwanke, and Dave Stoller, whose relentless efforts and tireless dedication were paramount to the success of this project. David Bernard and Mike Wallendorf assisted with much of the analysis of the mark-recapture data and review of the report. Participants of the PU, subsistence and sport fisheries assisted by returning tags. Ahtna, Inc, Chitina Native Corporation, Al Taylor, and Randall Ashby granted permission to use their land for placement of radio tracking stations. Harley MacMahon and Jerry Lee provided air charter services for aerial tracking surveys. Sara Case finalized the report for publication. Steve Moffit aged all scale samples. The U.S. Fish and Wildlife Service provided partial funding of this study.

LITERATURE CITED

AAC (Alaska Administrative Code). 2000a. 5 AAC 24.360. In Alaska Fish and Game Laws and Regulations Annotated 200-2001 edition. Lexis Publishing, New York.

AAC (Alaska Administrative Code). 2000b. 5 AAC 24.361. In Alaska Fish and Game Laws and Regulations Annotated 200-2001 edition. Lexis Publishing, New York.

LITERATURE CITED (continued)

AAC (Alaska Administrative Code). 2000c. 5 AAC 01.647. In Alaska Fish and Game Laws and Regulations Annotated 200-2001 edition. Lexis Publishing, New York.

Arnason, A. N., C. W. Kirby, C.J. Schwarz, and J. R. Irvine. 1996. Computer analysis of data from stratified mark-recovery experiments for estimation of salmon escapements and other populations. Canadian Technical Report of Fisheries and Aquatic Science 2106:vi+37p.

Bendock, T. and M. Alexandersdottir. 1992. Mortality and movement behavior of hooked-and-released chinook salmon in the Kenai River recreational fishery, 1989-1991. Alaska Department of Fish and Game, Fishery Data Series No. 92-2. Anchorage.

Burger, C. V., R. L. Wilmot, and D. B. Wangaard. 1985. Comparison of spawning areas and times for two runs of chinook salmon (*Oncorhynchus tshawytscha*) in the Kenai River, Alaska. Canadian Journal of Fisheries and Aquatic Sciences, 42: 693-700.

Chapman, D. G. 1951. Some properties of the hypergeometric distribution with applications to zoological censuses. University of California Publications in Statistics. No.1:131-160.

Darroch, J. N. 1961. The two-sample capture-recapture census when tagging and sampling are stratified. Biometrika 48:241-260.

Efron, B.I. and R. J. Tibshirani. 1993. An introduction to the bootstrap. Monographs on statistics and applied probability 57. Chapman and Hall, New York.

Eiler, J. H., B. D. Nelson, and R. F. Bradshaw. 1991. Radio tracking chinook salmon (Oncorhynchus tshawytscha) in a large turbid river. In A. Uchiyama and C. J. Amlaner, Jr, editors. Proceedings of the Eleventh International Symposium on Biotelemetry. Waseda University Press, Tokyo.

Eiler, J. E. 1995. A remote satellite-linked tracking system for studying pacific salmon with radio telemetry. Transactions of the American Fisheries Society 124:184-193.

Gray, R. H. and J. M. Haynes. 1979. Spawning migration of adult chinook salmon (Oncorhyncus tshawytsha) carrying external and internal radio transmitters. Journal of the Fisheries Research Board of Canada 36: 1060-1064.

Koski, W. R., M. R. Link, and K. K. English. 1993. Distribution, timing, fate and numbers of chinook salmon returning to the Nass River watershed in 1992. Report NF92-08 prepared by LGL Ltd, Sidney, B.C. for Nisga'a Tribal Council, New Aiyansh, B.C.

Koski, W. R., R. F. Alexander, and K. K. English. 1994. Distribution, timing, fate and numbers of chinook salmon returning to the Nass River watershed in 1993. Report NF93-05 prepared by LGL Ltd, Sidney, B.C. for Nisga'a Tribal Council, New Aiyansh, B.C.

LaFlamme, T. R. 1997. Creel and escapement estimates for chinook salmon in the Gulkana River, 1996. Alaska Department of Fish and Game, Fishery Data Series No. 97-12, Anchorage.

McPherson, S. A., D. R. Bernard, M. S. Kelley, P. A. Milligan, and P. Timpany. 1997. Spawning abundance of chinook salmon in the Taku River in 1996. . Alaska Department of Fish and Game, Fishery Data Series No. 97-14. Anchorage.

Merritt, M. F. and K. Roberson. 1986. Migratory timing of upper Copper River sockeye salmon stocks and its implications for the regulation of the commercial fishery. North American Journal of Fisheries Management, 6:216-225.

Mosher, K. H. 1969. Identification of Pacific salmon and steelhead trout by scale characteristics. United States Department of the Interior, U.S. Fish and Wildlife Service, Bureau of Commercial Fisheries, Washington, D.C., Circular 317.

Mundy, P. R. 1979. A quantitative measure of migratory timing illustrated by application to the management of commercial salmon fisheries. Phd. Dissertation. University of Washington.

LITERATURE CITED (continued)

Pahlke, K. E. and D. R. Bernard. 1996. Abundance of the chinook salmon escapement in the Taku River, 1989 to 1990. Alaska Fisheries Research Bulletin 3(1):9-20.

Pahlke, K. and P. Etherton. 1999. Abundance and distribution of the chinook salmon escapement on the Stikine River, 1997. Alaska Department of Fish and Game, Fishery Data Series No. 99-6, Anchorage.

Ryan, P. and M. Christie. 1976. Scale reading equipment. Fisheries and Marine Service, Canada, Technical Report PAC/T-75-8, Vancouver.

Seber, G. A. F. 1982. The estimation of animal abundance and related parameters. Charles Griffin and Company, Ltd, London.

Taube, T. T. 2000. Area management report for the recreational fisheries of the upper Copper/upper Susitna River management area, 1998. Alaska Department of Fish and Game, Fishery Management Report 00-13, Anchorage.

Welander, A. D. 1940. A study of the development of the scale of the chinook salmon (*Oncorhynchus tshawytscha*). Master's thesis, University of Washington, Seattle.

Zar, J. H. 1984 Biostatistical analysis, second edition. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

APPENDIX A

Appendix A1.-Daily fishing effort, water level, catch, CPUE, tag deployment, and tagging rate of chinook salmon in the Copper River, 1999.

Date	Fishing Effort (hr)	Water Level (cm)	Catch	CPUE (catch/hr)	Cumulative CPUE (catch/hr)	Radio Tags Deployed	Tagging Rate
23-May	6		0	0	0	0	0.00
24-May	6		0	0	0	0	0.00
24-May	6		0	0	0	0	0.00
25-May	6		0	0	0	0	0.00
26-May	6		0	0	0	0	0.00
27-May	6		0	0	0	0	0.00
28-May	6		0	0	0	0	0.00
29-May	6		0	0	0	0	0.00
30-May	6	18	1	0.2	0.2	1	1.00
31-May	6	3	1	0.2	0.4	0	0.00
1-Jun	6	43	8	1.3	1.7	7	0.88
2-Jun	6	25	23	3.8	5.5	15	0.65
3-Jun	6	43	13	2.2	7.7	7	0.54
4-Jun	6	18	25	4.2	11.9	13	0.52
5-Jun	6	23	17	2.8	14.7	9	0.53
6-Jun	6	36	19	3.2	17.9	10	0.53
7-Jun	6	61	10	1.7	19.6	5	0.50
8-Jun	6	86	20	3.3	22.9	10	0.50
9-Jun	6	124	11	1.8	24.7	6	0.55
10-Jun	6	132	21	3.5	28.2	11	0.52
11-Jun	6	140	18	3	31.2	11	0.61
12-Jun	6	155	12	2	33.2	9	0.75
13-Jun	6	170	19	3.2	36.4	12	0.63
14-Jun	6	185	16	2.7	39.1	11	0.69
15-Jun	6	196	46	7.7	46.8	31	0.67
16-Jun	6	206	55	9.2	56.0	36	0.65
17-Jun	6	208	34	5.7	61.7	17	0.50
18-Jun	6	234	43	7.2	68.9	22	0.51
19-Jun	6	226	44	7.3	76.2	22	0.50
20-Jun	6	216	38	6.3	82.5	19	0.50
21-Jun	6	216	44	7.3	89.8	22	0.50
22-Jun	6	211	36	6	95.8	18	0.50
23-Jun	5	203	37	7.4	103.2	19	0.51
24-Jun	4	201	26	6.5	109.7	13	0.50
25-Jun	5	198	35	7	116.7	18	0.51
26-Jun	5	208	46	9.2	125.9	23	0.50
27-Jun	5	208	33	6.6	132.5	16	0.48
28-Jun	5	206	36	7.2	139.7	12	0.33
29-Jun	5	208	47	9.4	149.1	15	0.32
30-Jun	5	213	37	7.4	156.5	9	0.24
1-Jul	2	206	12	6	162.5	3	0.25
2-Jul	0		0	0	162.5	0	0.00

-continued-

Appendix A1.-Page 2 of 2.

Date	Fishing Effort (hr)	Water Level (cm)	Catch	CPUE (catch/hr)	Cumulative CPUE (catch/hr)	Radio Tags Deployed	Tagging Rate
3-Jul	1		0	0	162.5	0	0.00
4-Jul	5	246	10	2	164.5	3	0.30
5-Jul	5	251	7	1.4	165.9	2	0.29
6-Jul	5	251	12	2.4	168.3	4	0.33
7-Jul	5	251	7	1.4	169.7	3	0.43
8-Jul	5	259	7	1.4	171.1	3	0.43
9-Jul	5	259	17	3.4	174.5	5	0.29
10-Jul	5	208	10	2	176.5	4	0.40
11-Jul	5	234	8	1.6	178.1	2	0.25
12-Jul	5	236	6	1.2	179.3	3	0.50
13-Jul	5	236	15	3	182.3	8	0.53
14-Jul	5	224	9	1.8	184.1	4	0.44
15-Jul	4	234	8	2	186.1	4	0.50
16-Jul	5	269	5	1	187.1	3	0.60
17-Jul	5	284	5	1	188.1	3	0.60
18-Jul	5	287	4	0.8	188.9	2	0.50
19-Jul	5	259	6	1.2	190.1	3	0.50
20-Jul	5	257	6	1.2	191.3	3	0.50
21-Jul	5	257	5	1	192.3	3	0.60
22-Jul	2.5	262	2	0.8	193.1	1	0.50
23-Jul	5	262	2	0.4	193.5	1	0.50
24-Jul	5	262	2	0.4	193.9	1	0.50
25-Jul	5	257	2	0.4	194.3	1	0.50
26-Jul	5	269	1	0.2	194.5	1	1.00
27-Jul	5	277	3	0.6	195.1	1	0.33
28-Jul	5	287	1	0.2	195.3	1	1.00
29-Jul	2.5	292	1	0.4	195.7	0	0.00
30-Jul	2.5	292	0	0	195.7	0	0.00
31-Jul	5	292	1	0.2	195.9	1	1.00
1-Aug	5	302	0	0	195.9	0	0.00
2-Aug	5	328	0	0	195.9	0	0.00
Totals			1,045			522	

APPENDIX B

Appendix B1.-Capture histories for all spaghetti-tagged-only chinook salmon marked and harvested in the Copper River, 1999.

Week of Marking	Week of Recapture[a] 1	2	3	4	5	6	7	8	9	Number Recaptured	Number Marked	Number not Recaptured	Recapture Rate
1 (June 1-June 7)	0									0	44	44	0.00
2 (June 8-June 14)		1	1							2	51	49	0.04
3 (June 15-June 21)			7	10	2					19	128	109	0.15
4 (June 22-June 28)				12	6	2				20	133	113	0.15
5 (June 29-July 5)					9	2				11	71	60	0.15
6 (July 6-July 12)						2	5	1	1	9	50	41	0.18
7 (July 13-July 19)							1	2	1	4	20	16	0.20
8 (July 20-July 26)								1	1	2	7	5	0.29
9 (July 27-Aug 3)									0	0	3	3	0.00
Total Recaptured	0	1	8	22	17	6	6	4	3	67	499	432	0.13
Number Unmarked Caught in PU Fishery	0	365	698	2,080	1,141	583	392	211	96				
Number Caught in PU Fishery	0	366	706	2,102	1,158	589	398	215	99				

[a] Week of recapture same as week of marking. Weeks ran from Tuesday-Monday.